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The Diadochokinetic Skills of Children with Speech Difficulties

By:

Pamela Williams

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

The University of Sheffield

Department of Human Communication Sciences

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Abbreviations and conventions

Abbreviations	
A	Articulation difficulties/disorder
AA	Articulation Age
ASHA	American Speech- Language and Hearing Association
C	Consonant
CA	Chronological age
CAS	Childhood apraxia of speech
sCAS	Suspected Childhood apraxia of speech
CCD	Common Clinical Distortions
CPD	Consistent Phonological Disorder
CV	Consonant-vowel (and other syllable structures: CVCV, CVC, CVCVC, CCVC)
DDK	Diadochokinesia; Diadochokinesis, Diadochokinetic;
DEAP	Diagnostic Evaluation of Articulation and Phonology (Dodd, Hua, Crosbie, Holm & Ozanne, 2002)
DVD	Developmental Verbal Dyspraxia
IPD	Inconsistent Phonological Disorder
IQ	Intelligence Quotient
MDT	Mispronunciation Detection Task
NHS	National Health Service
NT	Not tested
NW	Non-word(s)
PCC	Percentage Consonants Correct
PPC	Percentage Phonemes Correct
RCSLT	Royal College of Speech and Language Therapists
RW(s)	Real words(s)
s.d.	Standard deviation
SS(s)	Syllable sequences
SLP	Speech and Language Pathologist
SLT	Speech and Language Therapist
SLTA	Speech and Language Therapy Assistant
TD	Typically-developing
V	Vowel

Conventions

Clinical children or Clinical group are used for ease of reference to refer to the children with speech difficulties as individuals or as a group.

Small capitals e.g. BABY are used to represent a spoken real word target in naming or repetition tasks.

Abstract

The Diadochokinetic Skills of Children with Speech Difficulties

Background and Purpose

Diadochokinetic skills (DDK) are thought to reflect speech motor competence. However, there is limited information concerning DDK performance in children with speech difficulties (SD) and how it relates to performance on other speech measures.

The main purpose of this study was to investigate relationships between DDK accuracy, consistency and rate and measures of speech and oro-motor skill. A related aim was to identify whether there are distinct DDK profiles that map onto proposed subgroups of speech difficulty such as Developmental Verbal Dyspraxia (DVD).

Method

Forty children with SD in the age range 4;0-7;11 were assessed on DDK tasks involving a range of stimuli types and lengths, along with a battery of speech and oro-motor assessments. The children's performance was compared to that of forty age-matched typically-developing (TD) children.

Results

The children with SD performed more poorly than the TD group on all three DDK measures. DDK accuracy correlated strongly with accuracy on speech output tasks and on an input task of mispronunciation detection. DDK consistency correlated with consistency on a single-word naming task. No correlation was found between DDK rate and other speech tasks. Furthermore, no relationship was found between DDK performance and oro-motor skills. Six distinct DDK profiles were identified in the group of children with SD but there was no robust evidence that these profiles map onto the subgroups of speech difficulty that have been proposed in the literature.

Conclusion and Implications

DDK skills should be assessed and evaluated in the context of performance on other speech tasks. Theoretical implications are discussed and recommendations for clinical practice are made regarding methods for administering DDK tasks. There was little support for DDK being a unique marker of DVD, rather it appeared to be a marker of speech difficulties in general.

Chapter One

Introduction and Literature Review 1

DDK Studies and Classification of Children's Speech Difficulties

1.1 Introduction

Diadochokinesis (DDK) refers to the ability to perform rapidly alternating muscular movements, such as flexion and extension of a limb, pronation and supination of the hand and side to side movements of the tongue. The term has also been applied to speech, as the ability to perform repetition of syllables at a maximum rate of production (Fletcher, 1978).

DDK tasks for speech require a participant to imitate mono-syllables, such as /pə/, /tə/, /kə/ and/or a nonsense sequence, involving two or three syllables and consonant sounds made with different articulatory placements e.g. /pətə/ or /pətəkə/, and then repeat that target three, five, or ten times as fast as possible. For young children, two and three syllable real words, involving consonant sounds with different phonetic placements e.g. PARTY or PAT-A-CAKE, may be used instead or in addition to nonsense sequences. Such DDK tasks allow measurements to be made of an individual's ability to:

> "....rapidly start and stop the movement of the articulators and to execute repetitive, alternating, sequential movements typically associated with speech articulation" (Johnson, 1980, p.63; Cohen, Waters & Hewlett, 1998).

DDK is considered to be a task which is not affected by the many phonological complications of conversational speech (Tiffany, 1980; Yaruss & Logan, 2002), but which approximates the co-ordination and execution of rapid articulatory movements which take place in spontaneous speech. For this reason, speech and language therapists (SLTs) use DDK tasks to assess speech motor skills both with adults who have speech difficulties following a cerebral vascular accident or consequent to a neurological condition, with adults and children who stammer, and with children who have developmental speech difficulties.

The subject of this thesis is DDK performance by children with developmental speech difficulties. These are children who have difficulties making speech sounds and using them in words and sentences, with the result that their speech is unclear and listeners experience difficulties in understanding what they are saying. Speech difficulties are recognised to be the most common paediatric communication disorder (Verdon, McLeod & Wong 2015; McLeod & Harrison, 2009; ASHA, 2000; Law, 1992). However, prevalence numbers vary considerably depending on whether children who have known and unknown aetiologies are included. Isolated speech impairment (i.e. in the absence of other co-occurring conditions) has been estimated to affect between 2.3% to 24.6% in children under 16 years (Law et al., 2000), but the median prevalence estimate is approximately 6% (McCormack et al., 2009; Rvachew & Brosseau-Lapre, 2012). The numbers are greater in younger children with a prevalence rate of 7.5% being reported for isolated speech impairment (i.e. without associated or co-occurring language problems) in children aged 3-11 years (Shriberg & Kwiatkowski, 1994; Lee & Gibbon, 2015).

Children with speech difficulties are not a homogeneous group; they differ in terms of their presenting speech errors, the severity of their speech difficulties, the underlying cause of their difficulties, the involvement of other aspects of language and literacy, their prognosis and their response to treatment (Dodd, 2005; Dodd & McIntosh, 2008). Different approaches have been proposed for how best children's speech difficulties should be classified. However, as of yet there is no clear consensus agreement and this remains an unresolved issue in speech pathology.

Although some children's speech difficulties improve spontaneously during their pre-school and early school years, others do not and require referral to speech and language therapy services for assessment and intervention. The outcomes for children who receive speech and language therapy are generally positive (Law et al., 1998; 2000; Rvachew & Brosseau-Lapre, 2012), but the length of time required for intervention will vary according to the child's individual profile of strengths and weaknesses. Despite this often positive outcome, the consequences of having speech difficulties during the pre-school and early school years can be significant and potentially long-term. In addition to the communication breakdown which frequently occurs as a result of the speech errors made, a speech problem can affect the child's ability to develop social relationships with both peers and adults (McCormack et al., 2009). Children often experience feelings of failure and/or frustration at not being understood and these affect the child's overall emotional well-being, confidence and self-esteem (Nash & Stenglehofen, 2002; Hartshorne, 2006; Bercow, 2008). Literacy acquisition may also be affected, particularly if the speech difficulties persist beyond 5 ½ year (Snowling, Bishop &

Stothard, 2000; Nathan et al., 2004; Leitao, Fletcher & Hogben, 2004;) and this in turn inhibits academic progress at school (Teverovsky, Bickel & Feldman, 2009).

It is recognised in clinical practice and in the literature that children with speech difficulties of differing ages, often experience difficulties in performing DDK tasks (Yoss & Darley, 1974; Henry, 1990; Ozanne, 1995; Preston & Edwards, 2009; Murray et al., 2015). However, interpretation of an individual child's performance on DDK tasks is not straight-forward and studies have applied different methodologies which makes it difficult to compare results. Furthermore, although there is now an amount of evidence concerning DDK performance in typically-developing children, there is still limited information available about DDK performance in children with speech difficulties. In studies which have included children with speech difficulties, there has not always been a detailed description of the nature of the individual children's speech difficulties and the ages of the children studied have varied. Furthermore, there has been little attempt to relate a child's performance on DDK tasks with their performance on other aspects of speech processing.

To address gaps in the current literature, the present study aimed to:

- carry out a comprehensive investigation of the DDK skills of a group of children with speech difficulties, involving a range of tasks, different measurements and scoring procedures.
- compare the children's performance to that of a group of age-matched typically-developing children.
- provide detailed information concerning the nature of the individual clinical[1] children's speech difficulties using a range of assessment procedures and by applying different theoretical approaches to classification proposed in the literature.
- investigate the relationship between the clinical children's DDK performance and their performance on other speech processing measures.
- identify whether the children showed distinct DDK profiles (in terms of accuracy, consistency and rate) and if so, whether these map onto any subgroups proposed in the literature.

[1] Clinical children or clinical group are used for ease of reference to refer to the children with speech difficulties as individuals or as a group –please see glossary.

The thesis is organised into nine chapters. In chapter one and two there is a literature review of what is known currently about DDK performance and children's developmental speech difficulties. The research questions addressed in the study are listed at the end of chapter two and chapter three describes the methodology used to address these. Chapters four to eight describe the results and chapter nine provides a discussion of the findings in the context of current knowledge and details the theoretical and clinical implications, the strengths and limitations of the study, and directions for further research.

1.2 Introduction to Literature Review

In this chapter the review of the current literature will start with a description of the terminology which will be used, followed by a critical review of DDK performance by children with speech difficulties and a summary of normative DDK performance. It will continue with a review of classification approaches which have been applied to children's speech difficulties: medical, linguistic and psycholinguistic.

The literature review will continue in chapter two with a review of typical and atypical speech motor development in children and how this relates to development of DDK skills. This is followed by a review of assessment approaches and procedures which have been applied to children's speech difficulties and will include a detailed review of task design, measurements, and procedures which have been used to investigate DDK skills. Finally, the research questions for the current study will be listed, which have been formulated in the context of the literature reviews in chapters one and two.

1.3 Terminology

The standard measure of DDK performance is articulatory speed (Preston & Edwards, 2009) and the terms diadochokinetic rate and maximum repetition rate have been used variously in the literature by different authors. In this thesis, measures of DDK performance in addition to rate will be explored and therefore a more general term of diadochokinetic skills will be used.

Terminology varies for how children with speech difficulties are best described. A wide range of descriptive terms can be found in the literature over the past twenty years including: speech disorder (Dodd, 1995; 2005); speech difficulties (Stackhouse & Wells, 1997; 2001; Pascoe, Stackhouse & Wells, 2006); speech impairment (McLeod & McCormack, 2007); speech sound disorders (Bowen, 2009; 2015; Williams, McLeod & McCauley, 2010); phonological problems (Joffe & Pring, 2008); (developmental) phonological disorders (Rvachew & Brosseau-Lapre, 2012). This is despite recommendations for terminology having been made by professional bodies. For example, ASHA (2004) advised that speech sound disorders is the preferred term in USA, whereas RCSLT (2009; 2011) prefer speech impairment, when referring to the same group of children in UK.

Broad umbrella terms covering a wide range of speech problems appear to be currently favoured. For example, speech sound disorders were defined by the International Expert Panel on Multilingual Children's Speech (IEPMCS) (2012) and quoted in Verdon, McLeod and Wong (2015) as:

> "any combination of difficulties with perception, articulation/motor production, and/or phonological representation of speech segments (consonants and vowels), phonotactics (syllable and word shapes), and prosody (lexical and grammatical tones, rhythm, stress and intonation) that may impact speech intelligibility and acceptability.... of both known... and presently unknown origin" (p.49).

Another broad umbrella term in current use is speech difficulties, which were defined by Pascoe et al. (2006), as:

> "....children who have difficulties with producing speech segments in isolation, single words or in connected speech regardless of origin of difficulty." (p.2).

This is the term which will be mainly utilised in this thesis, but when describing specific studies the terms used by the authors such as speech impairment, speech delay/disorder, phonological delay/disorder and speech sound disorder will occur.

In the literature, DDK performance in children has been particularly associated with the motor speech condition currently known as Childhood Apraxia of Speech (CAS) in USA, which replaced the previous terminology of Developmental Apraxia of Speech (DAS) (ASHA, 2007). CAS was defined as:

> "a neurological childhood (pediatric) speech sound disorder in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g. abnormal reflexes, abnormal tone). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known or unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and/or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody." (ASHA, 2007).

In the UK, the term Developmental Verbal Dyspraxia (DVD) is used in preference to CAS, but largely describes the same population of children, with some exceptions (RCSLT, 2011). DVD was defined in the RCSLT Policy Statement (2011) as:

> "a condition where the child has difficulty in making and co-ordinating the precise movements which are used in the production of spoken language, although there is no damage to muscles or nerves." (after Ripley, Daines & Barrett, 1997).

DVD will be the term of choice in this thesis but DAS, CAS and DVD will be used when describing the research literature.

1.4 DDK Performance by Children with Speech Difficulties

Children with speech difficulties have been reported to have problems performing spoken DDK tasks, either because of slow rate of production and/or consonant sequencing difficulties (Yoss & Darley, 1974; Aram & Horwitz, 1983; Henry, 1990; Ozanne, 1995; Murray et al., 2015). However, here has been a long-standing debate in the literature as to whether DDK performance could be a specific marker of developmental verbal dyspraxia (DVD).

1.4.1 DDK proposed as a clinical marker of DVD

Over forty years ago, Yoss and Darley (1974) proposed that performance on spoken DDK tasks is one of the factors that can help differentiate a motor speech disorder from other speech disorders. In their study, 30 children, aged 5-9 years (range 5;1-9;10, mean 6;4), with moderate or severe articulation difficulties of unknown aetiology, but with average verbal intelligence and language skills, were matched by chronological age and gender to 30 typically developing controls. All the children underwent a battery of tests, which included an auditory perception and discrimination test; non-speech oro-motor tasks (isolated and sequenced volitional oral movements); DDK tasks (repetition of mono-syllables and a tri-syllable) and speech production tasks (real and nonsense words, conversational speech and a story re-tell task). The children with speech difficulties also underwent a paediatric neurological examination. Highly significant differences were found between the two groups, with the children with speech difficulties performing more poorly than the typically-developing controls on all measures.

Yoss and Darley (1974) then considered whether the children with speech difficulties could be subdivided. Each child's performance on the test of isolated volitional oral movements (IVOM) (modified from De Renzi et al., 1966) was compared to that of their age-matched control and a difference score was calculated. The median point on the distribution of difference scores (for all the children) was selected as the dividing line. Fourteen children fell above the median point and were designated as Group 1, who had good performance on the IVOM. The remaining sixteen fell below the median point and were designated as Group 2, who had poor performance on the IVOM. The results from the paediatric neurological examination showed that 15 of the 16 children in Group 2 had some neurological evidence of developmental immaturity, for example difficulties in silent alternate motion rates of the tongue (e.g. waggling tongue from side to side); difficulties in manipulating scissors, buttons, zips and shoelaces; difficulties riding a bicycle or tricycle; frequent falls and awkward movements observed during play in a playground. In comparison, only four of the 14 in Group 1 showed such evidence. On spoken DDK tasks, children in both groups 1 and 2 performed similarly when asked to produce rapid repetitions of the mono-syllables /pʌ/ and /tʌ/. However, the Group 2 children performed at a slower rate when attempting to repeat the mono-syllable /kʌ/ and the tri-syllable /pʌtʌkʌ/, than the children in Group 1. The authors also reported that the children had difficulties in maintaining the correct syllable sequence on the tri-syllable task. However, it should be noted that only seven of the fourteen children in group 1 and three of the sixteen children in Group 2 managed to achieve the sequence /pʌtʌkʌ/ at all.

The above difficulties affecting co-ordination of oral movements, fine and gross motor movements, and spoken DDK skills were felt to be indicative of 'soft' neurological signs. Yoss and Darley (1974) diagnosed the children in Group 2, as having developmental apraxia of speech (DAS), a difficulty with the motor planning and programming of speech, whereas the remaining children were described as having a functional articulation disorder. However, a subsequent study by Williams, Ingham and Rosenthal (1981) failed to replicate Yoss and Darley's findings (1974). When they administered the same test battery to a different group of 30 children with moderate-severe speech difficulties, Williams et al. (1981) could not subgroup the children on the basis of their performance on isolated and /or sequenced oral movements, nor on the basis of neurological findings. Since Yoss and Darley's (1974) results could not be replicated by Williams et al. (1981), this cast doubt on the validity of their recommendations for diagnosis of DAS. However, as observed by Rvachew and Brosseau-Lapre (2012), the two studies were not equivalent in terms of the clinical population sampled. Williams et al., (1981) recruited children from community clinics, who had less complex motor, oro-motor and speech presentations than those attending the specialised Mayo Clinic in the Yoss and Darley (1974) study. This participant selection difference is likely to explain why so few of the children in the Williams et al. (1981) study showed soft neurological signs and why they achieved higher scores overall on the test of volitional oral movements. Therefore, Yoss and Darley's (1974) findings, for the group of complex children they assessed and described as having DAS, may have been questioned unfairly. Further, although the subgroups in Yoss and Darley's study were not clear cut and the number in each was small, there has still been some support for their original findings.

Other studies carried out in the 1970s and 1980s also reported that children with DAS performed poorly on spoken DDK tasks and supported Yoss and Darley's (1974) advice that DDK tasks could be a useful tool for making a differential diagnosis of a motor speech disorder (Aram & Glasson, 1979; Aram & Horwitz, 1983; Milloy, 1986; Dewey et al., 1988). However, methodological issues with participant selection criteria continued to be a concern. For example, in some cases, performance on a DDK task was used to allocate children to a DAS group, and then a DDK task was included in the experimental test battery (Aram & Horwitz, 1983; Milloy, 1986). This led to a circular argument developing, whereby the criteria for allocating children to a DAS subgroup such as poor performance on spoken DDK tasks, effectively became the recognised features of DAS i.e. children with DAS perform poorly on spoken DDK tasks (Stackhouse, 1992).

More recent studies have attempted to adopt more stringent participant selection criteria. For example, Lewis et al. (2004) reported a longitudinal study involving thirty-nine children with speech difficulties, recruited, at age 4-6 years, from the caseloads of SLPs who were based in community settings or were working in private practice. All the children had normal hearing, normal IQ and no diagnosed neurological deficits, but were suspected to have CAS by their SLPs. The children were assessed (at T1) by the research team on a range of oro-motor (including DDK), speech and language tasks, and the group (n=39) was then subdivided into three participant groups:

(a) a group who met the criteria to be diagnosed with CAS (n=10)

(b) a group who did not meet the criteria for CAS but who had moderate to severe speech difficulties and no language difficulties (n=15) –described as isolated speech sound disorders (SD).

(c) a group who did not meet the criteria for CAS but who had language difficulties in addition to moderate to severe speech difficulties (n=14) –described as combined speech sound and language disorders (SLD).

In order to be included as a CAS group participant the children had to demonstrate four of the following eight characteristics of motor programming deficits: sequencing difficulties, trial and error groping, prosodic disturbances, metathetic errors (transposition of two consonants in complex words e.g. transposition of [s] and [k] in BISCUIT produced as [bɪksɪt]), decreased DDK rates, consonant deletions, increased errors on polysyllabic words, inconsistency in articulation with unusual error forms (based on criteria outlined by Stackhouse, 1992; Hall et al., 1993; Ozanne, 1995; Shriberg, Aram & Kwiakowski, 1997). In addition, they had to demonstrate reduced contrastive sound features in their phonemic repertoires (Dinnsen et al., 1990).

The results of the testing at T1 showed that the CAS group performed significantly differently to the SD group on all oro-motor, speech and language measures, but they could not be differentiated from the SLD group. The children were followed up and re-assessed when they were aged 8-10 years. At T2, the children in the CAS group still performed more poorly then the children in the SD group on all measures, but also performed more poorly than the children in the SLD group on some measures i.e. non-word repetition, language measures, spelling tasks and DDK. At T1, only 2/10 of the children with CAS could repeat a real word or nonsense DDK sequence (from Robbins & Klee, 1987) at all. By T2, 6/10 children with CAS were within one standard deviation of the mean for rate of production (on the *Fletcher Time-by-Count Test*, Fletcher, 1978) and their speech skills were reasonably accurate at a single word level and intelligible at a conversational speech level. Nevertheless, 8/10 of the children still made syllable sequencing errors on the DDK tasks.

Studies reported so far have examined whether DDK has a role in differentiating the condition DVD (CAS/DAS) as a motor speech impairment from other non-motor speech impairments. Thoonen et al. (1996) took a different approach and investigated whether it was possible to differentiate DAS from another motor speech impairment, developmental dysarthria, on the basis of maximum performance tasks (MPTs). MPTs attempt to examine the upper limits for the separate components of the speech mechanism: respiration, phonation and articulation (Kent, Kent & Rosenbek, 1987). The MPTs in the study by Thoonen et al. (1996) included: vowel prolongation, fricative prolongation, mono-syllabic repetition rate and tri-syllable repetition rate. They employed such tasks to quantify the speech motor capacities of three groups of children, aged 4-12 years: a group of typically-developing children, a group of children with spastic dysarthria and a group with DAS. The clinical children were recruited from three special speech and language schools in the Netherlands. The children with spastic dysarthria were identified from medical and educational records and on the basis of a cluster of speech, voice, resonance and prosodic features described by Yorkston, Beukelman and Bell (1987). The children with DAS were initially identified from medical and educational records and on the basis of speech criteria from checklists produced by Stackhouse (1992) and Hall et al. (1993). In particular, the children had to demonstrate: high rates of speech sound errors, inconsistent error patterns, groping behaviours and difficulties in articulating complex sound sequences in words. Initial diagnosis was made by the school based SLPs and this had to be re-confirmed unequivocally by the research SLPs before the children were included in the study. The results showed that the children with spastic dysarthria (n =9) could be differentiated from the other two groups on only two tasks: poor maximum vowel prolongation and slow mono-syllabic repetition rate. The children with DAS (n = 11) differed from the typically-developing controls (n =11) on maximum fricative prolongation and tri-syllable repetition rate. Further investigation of performance on the tri-syllable repetition task showed that the DAS group had a greater number of sequencing errors and required more attempts before an accurate sequence was produced.

In a subsequent study involving children mainly aged 4-12 years (but including some children aged 13-16 years), Thoonen et al. (1999) confirmed their previous findings regarding the role of MPTs in differential diagnosis of motor speech disorders. They confirmed that DAS can be diagnosed on the basis of maximum fricative prolongation, in combination with a difficulty in sequencing of speech movements as measured by performance on a multi-syllable rapid repetition task, such as /pataka/. Ease of production (attempts required to achieve the task) and tri-syllabic repetition rates were identified as sensitive measures to assess speech planning capacities in school aged children. In this second study, in addition to clinical groups with spastic dysarthria and DAS and typically-developing controls, Thoonen et al. (1999) also included a group of children described as having non-specific speech disorders. They reported that significant dysarthric or apraxic involvement was observed in some of the children with non-specific speech disorders, indicating that speech motor difficulties may occur in the wider population of children with speech difficulties, and not just those with a diagnosis of DAS or dysarthria. However, these findings must be treated with caution since they are based on findings from a very small cohort of children (n=11), with a wide age range (between 4;4 and 10;11) and with little specific detail provided of the nature of their presenting speech difficulties.

1.4.2 DDK questioned as a clinical marker of DVD

Ozanne (1995) noted the concerns expressed by Guyette and Diedrich (1981), that many characteristics included in checklists to identify DVD, could be found in the general population of children with speech difficulties. Ozanne (1995) recruited 100 children, aged 3;0-5;6, who had speech and/or language impairments and were on a waiting list for speech and language therapy in local (non-specialised) community clinics. The children were assessed on a battery of oro-motor, speech and language tests, with the aim of identifying whether or not they were showing evidence of motor programming and/or motor planning difficulties. Each child was scored on a list of 18 behaviours which had been identified from the literature as being indicative of motor programming and/or motor planning difficulties (Rosenbek & Wertz, 1972; Adams, 1990, Pollock & Hall, 1991): incorrect DDK sequence, slow DDK rate, increased errors with increased linguistic load, vowel errors, poor use of phonotactic structures, distortions, inconsistency, oral apraxia, consonant deletion, increased errors in polysyllabic words, non-rule bound errors, voluntary vs. involuntary performance, history of no babbling, prolongations/repetitions, groping, prosodic distortions, metathesis and epenthesis (insertion of an additional sound, often a vowel between two segments of a cluster e.g. SNOW produced as [sənəʊ]).

Ozanne (1995) reported that:

1. There appeared to be a continuum of motor impairment. Seventy-five percent of the children showed a mild deficit: of these, 55% had 0-1 motor behaviours and 20% had 2-3 behaviours. Only two children showed a large number of motor behaviours, both showing 13/18 behaviours.
2. Most motor behaviours were evident in between 14% and 38% of children, which appeared to support Guyette and Diedrich's (1981) views that commonly cited features of DAS/DVD also occur in the wider population of children with speech difficulties. The three most commonly occurring behaviours were: incorrect DDK sequence (shown by 38% of children), slow DDK rate (around 35%) and increased errors with increased linguistic load (around 27%)[2].
3. Some motor behaviours were seen rarely and only in a few children. These included: metathesis (n=3); prosodic disturbances (n=2); groping (n=3).
4. No child produced any examples of epenthesis.

Ozanne (1995; 2005) concluded that DDK accuracy and rate difficulties were quite common in her cohort (n=100), and not restricted to children with DVD/CAS. She therefore advised that DDK performance was not an appropriate diagnostic marker of DVD/CAS; more likely

[2] the results were only presented in a bar chart, with a numerical scale of 20%, 30% & 40%; exact % for slow DDK rate and increased errors with increased linguistic load, are not stated in the book chapters, (1995; 2005) and no other paper has been published on these results.

diagnostic marker candidates were motor behaviours, which occurred rarely such as metathesis, prosodic disturbances, groping and epenthesis.

Ozanne's (1995; 2005) study design has advantages over other studies in that the age range of the children was small (3-5 years), the numbers of children in the cohort were reasonably large (n=100) and it involved children on a waiting list for speech and language therapy, thereby eliminating differing amounts of therapy input as a variable. The study results highlighted the problems which exist in using checklists to identify children with DVD/CAS, especially if no detail is given of the number of checklist items required in order to make the diagnosis, and questioned the reliance on particular criteria such as DDK performance.

A study by Bradford and Dodd (1996) also raised concern regarding DDK being an appropriate diagnostic marker for DVD. They assessed 51 children with speech disorders, referred by SLPs, aged 3; 2 – 6; 7, and 51 chronological age-matched controls, on tasks assessing oro-motor skills, DDK skills, fine motor skills and novel word learning. Following assessment, the clinical group were divided into subgroups: speech delay (n=22), consistent deviant disorder (n=15), inconsistent deviant disorder (n=9) and developmental verbal dyspraxia (DVD) (n=5). Group assignment was made independently by two SLPs on the basis of the children's performance: (a) in a connected speech sample, (b) on the 25 Word Test[3] (Dodd, 1995), (c) on the Oral and Speech Motor Protocol (Robbins & Klee, 1987), and (d) on the presence/absence of behaviours indicative of speech-motor programming (Ozanne, 1995). Children were assigned to the speech delay subgroup if they demonstrated typical but delayed phonological simplification processes (PSPs) and to the consistent deviant subgroup if they demonstrated atypical PSPs. They were assigned to the inconsistent deviant subgroup if they demonstrated the use of unusual phonological errors and scored a level of 40% or more inconsistency when asked to name 25 selected words[4] (Dodd, 1995) on three occasions within the same session. The 40% criterion reflects production of at least 10 of the 25 words differently on at least two of the three occasions that they are elicited. Children in the DVD group had to show evidence of breakdown in each of the three levels of speech motor programming: phonological planning, phonetic programming and oro-motor and speech motor programme implementation (Ozanne, 1995, see Theoretical models, this chapter, 1.6.4.1 for further detail), during a

[3] Now known as the Inconsistency Assessment on the DEAP test (Dodd et al. 2002).

spontaneous speech sample and on the oro-motor assessment. In all the experimental groups, Bradford and Dodd (1996) reported that some children made errors on both the mono-syllable repetition tasks and the multi-syllabic DDK tasks. However, there were qualitative differences in the errors made by children in the different subgroups. Errors made by children in the control, delayed and consistent deviant groups were mainly attributable to the use of phonological simplification processes, whereas children in the inconsistent deviant group and the DVD group made articulation errors, syllable structure simplification errors or phoneme sequencing errors. Furthermore, the DVD group were reported to show the greatest proportion of prosodic disturbances, although the details are not specified. In addition, it was noted that a greater number of children in the inconsistent and DVD groups, compared to the control, delayed and consistent deviant groups, were unable to attempt or successfully complete the mono-syllable and multi-syllable rapid repetition tasks.

Bradford and Dodd (1996) concluded that DDK performance per se may not be able to differentiate between different subgroups of children with speech disorders. Some of their results need to be treated with caution since participant numbers were small when the children were divided into 4 subgroups e.g. only five children were included in the DVD group. However, they do suggest that a detailed evaluation of DDK performance could yield some important information, regarding the nature of the error types made by different subgroups of children.

In a more recent study, Dodd and McIntosh (2008) reported findings utilising the DDK task from the DEAP (Dodd et al., 2002) rather than the DDK tasks from the *Oral and Speech Motor Protocol* (Robbins & Klee, 1987). Parents referred 275 pre-school children to the study in response to advertisements placed in parish newsletters, preschools and child care centres in SE Queensland. The children were assessed on a standardized speech assessment and 78 of the 275, scored more than one standard deviation below the mean and were deemed to have atypical speech development. These children were aged 37-66 months (mean age 4.5 years) and their performance on tasks assessing input processing, cognitive linguistic and oro-motor skills was compared to that of 87 controls (from the cohort of 275) matched by chronological age and gender. The assessment of oro-motor skills included a DDK task which was scored in three different ways: (a) accuracy of consonant sound sequence (correct against an adult model), (b) intelligibility (clear or decipherable pronunciation of the consonant sounds, irrespective of accuracy) and (c) fluency (fluent productions with no groping, delayed response or hesitations within the word). Dodd and McIntosh (2008) reported that only 3.9% of the speech difficulty group performed below the normal range on the DDK task (based on normative data from the DEAP test (Dodd et al., 2002), compared to 0% of children from the control group. In all cases the poor performance of the speech difficulty group, could be primarily attributed to substitution of [t] for [k] on production of PAT-A-CAKE, leading to low accuracy scores but age appropriate intelligibility and fluency. Overall Dodd and McIntosh (2008) reported few children with speech difficulty performed poorly on the DDK task. This is clearly a different finding to that reported by Bradford and Dodd (1996) where difficulties on DDK tasks were common. This may be accounted for by the participant selection criteria in the 2008 study, which excluded children with neurological or cognitive impairment and any child who made a high number of inconsistent speech errors on the same lexical item. Therefore, it could be argued that children presenting with the most severe and complex speech difficulties did not take part in this study. Further support for this view is that the children were referred to the study by parents rather than by SLPs, which may also have resulted in children with less severe and less complex difficulties being recruited.

Henry (1990) reported a study involving young children with speech difficulties, similar in age to those included in the Dodd and McIntosh (2008) study, but with very different results. She recruited 30 children, aged 3-5 years, who were receiving speech and language intervention at the Nuffield Hearing and Speech Centre. All were described as having severe speech disorders who met a range of inclusion criteria, including making multiple articulation errors and having unintelligible connected speech. These children, as well as 60 typically-developing children in the same age range, were assessed on three tasks: oral DDK rates, non-linguistic rhythmic skills and auditory sequential memory. The clinical group scored significantly less well than the typically-developing group on all three tasks. As a group, the clinical children's rate of production on DDK tasks increased with age (possibly as a result of receiving speech and language intervention), but the correlation between age and speed was weaker than that of the typically-developing children suggesting that the clinical children had persisting speech motor constraints. On the DDK tasks, the clinical group showed a particular problem with the sequencing of different sounds rather than with repetitions of the same sound.

The findings from Henry's (1990) study showed that many more children with speech difficulties had DDK difficulties, compared to the 3.9% reported by Dodd and McIntosh (2008). All of Henry's (1990) cohort are described as having severe speech disorders (used by the author to avoid a terminology debate), and they were receiving speech and language intervention at the Nuffield Hearing and Speech Centre, which specialises in children with DVD and other severe speech difficulties. Thus, it seems likely they had more severe and complex presentations than the children included in the Dodd and McIntosh (2008) study. Participant selection is once again identified as crucial in explaining the discrepant results, similar to the differences between the studies by Yoss and Darley (1974) and Williams et al. (1981).

1.4.3. Individual DDK profiles in children with speech difficulties

Williams and Stackhouse (1998) reported the DDK performance of three case studies of children with obvious speech difficulties, aged 4-8 years, in comparison to 30 typically developing children, aged 3-5 years (Williams & Stackhouse, 2000). They utilised the DDK battery described in Williams (1996) and Williams and Stackhouse (2000). The children with speech difficulties were all monolingual English speakers and had no significant hearing loss, medical condition or physical disability and each had verbal comprehension sufficiently developed to cope with the demands of the tasks. Although they showed different surface level speech error patterns, each had an articulation age (AA), as measured by the Edinburgh Articulation Test (Anthony et al., 1971), within the 3-5 year old age range. The children were therefore matched on AA to the typically-developing children and their performance on the DDK tasks was compared through the use of z-scores. An individual DDK profile in terms of accuracy, rate and consistency was produced for each of the three children:

- Zoe (CA: 4;04; AA: 3;03) only had difficulty with accuracy on DDK tasks. She performed no differently to typically-developing chronological age matched and articulation age-matched children on rate and consistency.
- Vicky (CA: 8;07; AA: 4;05) had difficulties with accuracy and consistency on DDK tasks, but her rate was no different to that of the articulation age-matched typically-developing children.
- Sarah (CA: 5;0; AA: <3.00) had difficulties with accuracy, consistency and rate on the DDK tasks, which reflected the severe nature of her speech difficulties. Her scores were lower than chronological age-matched and articulation age-matched typically-developing children on virtually all tasks.

The results showed that not only did the children with speech difficulties perform differently from younger typically-developing children matched on AA but also that they performed differently from each other. Although the three children selected were similar in terms of the severity of their speech difficulties (as measured by their AA), they presented with different DDK profiles, in terms of accuracy, consistency and rate. Williams and Stackhouse (1998) proposed that the children's DDK profiles suggested different aetiologies to their speech difficulties: Zoe presented as a child with specific phonological delay, Vicky as a child with developmental verbal dyspraxia and Sarah as a child with a combination of dysarthric and dyspraxic features.

1.4.4 DDK findings from older children and adolescents

The findings from studies involving children 8 years and above, whose speech difficulties have persisted beyond the typical age of speech acquisition, has provided some useful information regarding the classification of the children who experience difficulties on DDK tasks. In particular, this evidence suggests it may be children who have continuing phonetic or articulatory difficulties rather than those with ongoing phonological difficulties who perform poorly on DDK tasks. These phonetic difficulties may occur as mild speech difficulties, affecting production of one consonant sound such as /s/ or /r/, or maybe far more widespread, resulting in a very restricted phonetic repertoire, as in DVD. For example, Preston and Edwards (2009) compared the performance of 13 adolescents (six male and seven female), aged 10-14 years, with residual speech errors, to that of 14 typically-developing (six male and eight female) peers on tasks assessing speed and accuracy of speech production. The residual speech difficulties shown by the adolescents included persisting difficulties with rhotics and other segmental difficulties with the production of alveolar and post-alveolar fricatives and affricates. The two groups were evaluated on an oral DDK task, which required rapid production of the tri-syllable /pʌtʌkʌ/, and two rapid naming tasks. Preston and Edwards (2009) reported no significant group differences in DDK rate, when examining both all attempts and correct productions only. However the children in the group with residual speech errors were less accurate and more variable in their production of the tri-syllables, even though none of them had persisting difficulties with production of the consonant sounds /p/, /t/ or /k/.

In another study involving older children, Wren, Roulstone and Miller (2012) investigated the speech skills of a large cohort of 991 children in the UK, who showed some continuing speech difficulties, at 8 years of age. The authors subdivided the children into 3 groups:

(1) Common Clinical Distortions (CCD): these children (n=582) presented with misarticulations of /s/ or /r/, similar to the group proposed by Shriberg (1993). Wren et al. (2012) observed that some listeners may consider these children to have a 'speech difference' rather than a 'speech error'.
(2) Persistent Speech Disorder (PSD): these children (n=263) showed a range of substitution, omission, distortion and addition errors and scored below -1.2 s.d. on the

PCC-A and PCC-late 8 (Shriberg et al., 1997). Wren et al. (2012) described these children as having a combination of phonetic and phonological difficulties. They made frequent and noticeable errors, which affected a large number of speech sounds.

(3) Non-Persistent Speech Disorder (Non-PSD): these children (n=141) also showed a range of substitution, omission, distortion and addition errors but did not meet the classification for PSD as they scored above -1.2 s.d. on the PCC-A and PCC-late 8 (Shriberg et al., 1997). Wren et al. (2012) described this group as having persisting phonological rather than phonetic difficulties and advised that their difficulties did not affect many speech sounds and were therefore not usually severe.

The authors compared the three groups on a range of measures including demographic factors, IQ performance, non-word repetition and DDK tasks. The DDK tasks were included as a measure of articulatory skill and required the children to repeat the tri-syllables /pətəkə/ and /bədəgə/ rapidly over a period of at least 10 seconds, and the number of accurate consonants was recorded. The findings showed that for most of the measures (gender, socio-economic status, IQ and non-word repetition) the PSD and Non-PSD groups were most similar. However, on the DDK tasks, the PSD and CCD groups were most similar, which led the authors to hypothesise that it is children with phonetic difficulties, whether mild as in the CCD group or more severe as in the PSD group, who are most likely to perform poorly on DDK tasks.

In a further study involving older children, Preston and Koenig (2011) investigated the phonetic variability of twenty children with residual speech sound difficulties, aged 9;02 -15;05 (mean 12;1), in order to determine whether distinct subgroups could be identified within the cohort. They scored token-to-token variability, using both acoustic and transcription-based measures on three tasks, (a) a tri-syllabic DDK task (as in the Preston and Edwards, 2009 study), (b) a 64-item picture naming task and (c) a 6 item multisyllabic rapid picture naming task. On the DDK task, variability/inconsistency was measured by a count of the number of versions produced in forty repetitions and on the lexical tasks, phonetic variability was scored using the Error Consistency Index (ECI) (Tyler, Lewis & Welch, 2003) and the Total Token Variability scale (TTV) (Marquardt et al., 2004). The results showed moderate correlations between the ECI and TTV transcription-based measures, but neither the ECI nor the TTV scores were strongly related to the DDK variability scores. Furthermore, the acoustic measures (e.g. voice onset time on DDK, word and DDK durations and vowel formant values) did not correlate well with each other or with the transcription-based measures. Preston and Koenig (2011) concluded that children who were highly variable on one task were not necessarily highly variable on other tasks and therefore they cautioned against attempting to sub-group older children's speech difficulties on the basis of phonetic variability.

1.4.5 Summary of DDK performance by children with speech difficulties

Children and adolescents with speech difficulties of varying types have been identified in the literature as having difficulties with DDK tasks, including slow rates of production as well as inaccurate and inconsistent repetitions. There is some evidence that it is children who have phonetic difficulties as distinct from phonological difficulties who perform particularly poorly on DDK tasks (Ozanne, 1995; Bradford & Dodd, 1996; Preston & Edwards, 2009; Wren et al., 2012). Case study evidence (Williams & Stackhouse, 2000) has led to a proposal that it may be possible to identify individual profiles of DDK difficulties, in terms of accuracy, consistency and rate, and to sub-group children with speech difficulties according to their DDK profile.

Whether or not DDK has a role in subdividing children who have /do not have a motor speech disorder has been the subject of debate in the literature. In particular, there has been controversy over DDK being a diagnostic marker for DVD, with some authors supporting such a role (Yoss & Darley, 1974; Thoonen et al., 1996; 1999; Lewis et al., 2004) and others disputing it (Williams et al., 1981; Guyette & Diedrich, 1981; Ozanne, 1995; 2005; Bradford & Dodd, 1996). This debate has been re-opened by Murray et al. (2015) who recruited seventy-two children, aged 4-12 years, suspected to have CAS by their local SLPs. Following initial screening by the research team, forty-seven children, were assessed on a battery of oro-motor, speech and language tasks: *The Oral and Speech Motor Protocol* (Robbins & Klee, 1987) which includes DDK tasks, a connected speech sample, *The Single Word Test of Polysyllables* (Gozzard, Baker & McCabe, 2006), the *DEAP Inconsistency Assessment* (Dodd et al., 2002) and the *Clinical Evaluation of Language Fundamentals* (Semel, Wiig & Secord, 2006). The authors advised that the gold-standard for diagnosing CAS is expert judgement of perceptual features. To meet this gold-standard, the first two authors made expert diagnoses of CAS against two sets of features: (1) the three consensus features in the ASHA (2007) technical report into CAS:

> "(a)inconsistent errors on consonants and vowels in repeated productions of syllables of words, (b)lengthened and disrupted co-articulatory transitions between sounds and syllables and (c) inappropriate prosody, especially in the realization of lexical or phrasal stress" (ASHA 2007b, pp.4, 54, and 59).

(2) 4 out of 10 features from the checklist of CAS characteristics produced by Strand, listed in Shriberg, Potter and Strand (2011). This resulted in the cohort of 47 children being subdivided into a group diagnosed with CAS (n=32) and a group who could not be diagnosed with CAS (n=15). The authors then used the children's scores on the different measures to carry out a

multivariate discriminant function analysis, in order to identify the combination of measures which best predicted the expert diagnosis of CAS. Four measures reached 91% diagnostic agreement with the expert opinions: syllable segregation, lexical stress matches, percentage phonemes correct (PPC) on the multi-syllabic naming task and articulatory accuracy on rapid repetition of the nonsense DDK sequence /pətəkə/ over a 3 second period. Murray et al. (2015) concluded that polysyllabic word accuracy and an oral motor assessment, which includes DDK tasks, may be sufficient to reliably diagnose CAS and rule out structural impairments and/or dysarthria. They advised that both the polysyllabic naming task and the DDK tasks are motorically challenging and elicit behaviours that underlie motor programming and planning deficits seen in CAS. Further research with a larger, unselected group of participants and a greater number of SLPs making the clinical diagnosis is required to validate the results of the Murray et al. (2015) study; however, their findings do appear to support a diagnostic role for DDK as proposed originally by Yoss and Darley (1974).

1.5 DDK Performance by Typically-developing Children

In contrast to findings for children with speech difficulties, typically-developing children have been reported to produce faster, more accurate and more consistent DDK repetitions with increasing age and with speech motor maturity.

Normative studies have examined spoken DDK rates in typically-developing English speaking children (e.g. Fletcher, 1972; Canning & Rose, 1974; Robbins & Klee, 1987; Henry, 1990; Williams & Stackhouse, 2000; Yaruss & Logan, 2002) and in children who speak other languages e.g. Thai (Prathanee et al., 2003), Portugese (Modolo et al., 2010) and Hebrew (Icht & Ben-David, 2014). Despite considerable methodological differences between studies, the overall consensus finding across languages is that spoken DDK rate improves with age, as a child's motor system matures (Kent et al., 1987; Henry, 1990). When exactly adult-like DDK rates are achieved, is the subject of debate and depends on the criteria used to indicate adult-like performance (Yaruss & Logan, 2002). Canning and Rose (1974) say that this is achieved at 9-10 years, but Fletcher (1978) suggested that this is not achieved until around 15 years of age.

One study, which investigated DDK performance in young children, reported a different result to most published studies (Williams & Stackhouse, 2000). Although there was a trend of increased rate with advancing age, typically-developing children aged 3-5 years showed no clear developmental progression in rate on the spoken DDK tasks. Thus, the older children did not produce significantly faster rates than the younger children. This finding was replicated by

Habgood (2000) for 6 and 7 year old children, utilising the same DDK protocol as that used by Williams and Stackhouse (2000) (see Stackhouse et al., 2007, chapter 7).

In addition to rate, Williams and Stackhouse (2000) included measures of accuracy and consistency in their normative investigation of DDK performance in young children. In contrast to rate findings, they reported a significant increase in accuracy with age, which replicated the few other studies where accuracy had been reported (Fletcher, 1972; Canning & Rose, 1974; Henry, 1990). Furthermore, consistency of production also increased significantly with age, but particularly between 3 and 4 years. Williams and Stackhouse (2000) concluded that measures of accuracy and consistency were more developmentally sensitive than rate measures for young children and should therefore be included in DDK protocols and procedures.

1.6 Classification of children's speech difficulties

An unresolved issue in speech and language pathology concerns the best way to classify speech difficulties in children given the heterogeneity of the population (Rvachew & Brosseau-Lapre, 2012; Waring & Knight, 2013). There has been some support for subdividing children with speech difficulties into two groups: those arising from a known aetiological cause, and those with 'functional' speech difficulties of unknown origin. However, further division than this has proved controversial and there are currently a number of classification systems in use, originating from medical, linguistic and psycholinguistic theoretical perspectives. These will be reviewed in this chapter.

1.6.1 Medical Classifications

Speech and language difficulties are classified according to 'clinical entity' in this approach. Labels in clinical use which are drawn from this perspective include 'apraxia', 'dyspraxia' and 'dysarthria'. Other terms used may actually be the cause of child's speech difficulties, such as 'hearing losses or 'cleft palate'. There are some advantages to adopting a medical classification system. For example, it may help a clinician to make a differential diagnosis, by observing commonly occurring symptoms and features of a particular condition. It may also help with giving a prognosis if the condition has been well-documented and reported. Furthermore, it may sometimes be possible to have medication or surgical intervention to improve a particular condition e.g. in the case of hearing loss or cleft palate and this is likely to result in improved speech outcomes (Stackhouse & Wells, 1997). The two major disadvantages to such an approach are: a) a medical diagnosis cannot always be made –in fact only a minority of children have speech difficulties arising from a known cause, b) it makes the assumption that individual children with a given label, will have the same speech and language profiles.

However, this is rarely the case - two children with the same label may differ considerably in their presenting difficulties (Stackhouse & Snowing, 1992a; Stackhouse et al., 2006). Thus, it is not possible to plan speech and language intervention based on a label.

Two types of medical classifications currently exist: those that are broad-based in that they include classifications for conditions other than communication disorders, and those that are specific to speech difficulties. DSM-5 (2013) and ICD-10 (2010) are examples of broad-based classification systems. At a basic level, these systems allow a differentiation to be made between children who only have speech difficulties, those who have a combination of speech and language difficulties, and those who have speech difficulties in the context of other pervasive disorders. However, such systems are usually too broad to make fine differential diagnoses of children with speech difficulties. However, one broad-based classification system, WHO ICF-CY (2007), has been suggested as an appropriate framework for use by speech and language professionals (Enderby, John & Petheram, 2006; McLeod & McCormack, 2007; McCormack et al., 2009). McLeod and McCormack (2007) provide a helpful guide to how a SLP/SLT can use the WHO ICF-CY framework in clinical practice to manage in a holistic manner children who have speech impairment. Consideration is given to the body structures and functions affected by the child's speech impairment as well as to the impact of the child's speech difficulties on their activities and participation.

Body Structures is the first level to consider. Structures most relevant to speech and language professionals include: s1 structures of the nervous system (including the brain); s2 structures of the eye and ear (including external, middle and inner ear); s3 structures involved in voice and speech (including structures of the nose, mouth, pharynx and larynx); and s430 structures of the respiratory system. For some children this is the origin of their speech difficulties, such as those with craniofacial anomalies (e.g. cleft palate) or those with a hearing loss (e.g. resulting from a malformed cochlea). This level is also involved when a neurological condition exists such as cerebral palsy, which then results in a speech impairment. However, for around 70-80% of children with speech difficulties, their body structures are intact and there is nothing to code at the Body Structures level. They are then classified as "speech impairment of currently unknown origin" (Shriberg et al., 2010).

Body functions is the next level to consider and this is the level of classification used most widely by SLPs/SLTs (McLeod, 2004). Impairments at this level include difficulties with the input, organisation and production of speech both at a segmental level (consonants and vowels) and at a supra-segmental level (timing and intonation). It is also the level where difficulties with intelligibility are coded along with any mismatches between a child's speech productions and those of their typically-developing peers. Specific relevant codes include: b3 voice and speech functions (including voice functions, articulation functions (b320), and fluency and rhythm of speech). It should be noted that these are broad categories and there is no classification for Phonological functions, as distinct from Articulation functions.

Activities and Participation are the levels where the severity and impact of the speech impairment are coded. Codes such as d3 communication, d330 activity of speaking and d350 activity of conversation are likely to be used by SLPs/SLTs. McLeod and McCormack (2007) illustrate how some specific codes might have application to individual children. For example, limitations in sounding out words (d1); difficulties in handling stress and psychological demands (d2); difficulties in engaging in interpersonal interactions (d6); difficulties in engaging play (d8). This framework can also be useful in distinguishing between a child's everyday/daily life performance and their performance on standardized tests used to assess speech production. For example, the following are useful measures of performance vs. capacity for SLPs/SLTs to consider:

- Production of single words compared to production of connected speech
- Imitated productions compared to spontaneous productions
- Stimulable vs. non-stimulable speech sounds
- Production of monosyllabic words vs. production of polysyllabic words

McCormack et al. (2009) carried out a systematic review of papers published during the previous 10 years which identified limitations in life activities associated with speech impairment. Using the Activity Limitations and/or Participation Restrictions as defined by the ICF-CY., 57 papers were found and these indicated that childhood speech impairments may be associated with difficulties in the following areas: learning to read/reading (d140/d166) , learning to write/writing (d145/d170), focussing attention (d160) and thinking (d163), calculating (d172), communication (d3), mobility (d4), self-care (d5), relating to persons in authority (d7400), informal relationships with friends/peers (d7500/d7504), parent-child relationships (d7600), sibling relationships (d7602), school education (d820)and acquiring, keeping and terminating a job (d845).

Contextual and personal factors can also be coded and these will include any relevant environmental factors. For example, it could include: the attitudes of family members and the child's peers to their speech difficulty, as well as any particular support needed in a given environment. Personal factors are those specifically relevant to an individual child, including risk factors typically associated with speech impairment.

Although relevant to children with speech difficulties, the ICF-CY (2010) is categorised as a broad-based aetiological classification by Waring and Knight (2013), since it includes classifications for many different conditions, not just those related to speech difficulties. In comparison, an example of an aetiological classification system, specific to speech sound disorders, is *The Speech Disorders Classification System* (SDCS) devised by Shriberg and colleagues (1994; 2010). This system was developed to address the issue of how to subgroup children's speech difficulties when there is no known aetiology. The current version of SDCS has 8 subgroups, each of which is proposed to have a number of diagnostic markers comprising distinct speech error patterns, and associated risk factors:

- Speech delay-genetic (SD-GEN)
- Speech delay –otitis media with effusion (SD-OME)
- Speech delay –psychosocial (SD-PSI)
- Motor speech disorder –apraxia of speech (MSD-AOS)
- Motor speech disorder –not otherwise specified (MSD-NOS)
- Speech errors -/r/ (SE)
- Speech errors -/s/ (SE)

The central tenet of this approach is that a consistent relationship exists between a genetic anomaly and a specific type of speech behaviour. Other than residual speech errors (affecting /s/ and /r/), which are caused by environmental factors alone, all the other aetiological subgroups are thought to be caused by a genetic variation, sometimes in conjunction with environmental factors. In terms of trajectory, speech delays (SD) are thought to normalise in the short-term i.e. by 6 years of age. In comparison, speech errors (SE) are thought to take longer to normalise, often persisting until around 9 years of age.

In their critical evaluation, Waring and Knight (2013) suggested that the SDCS currently has limited clinical application for SLPs/SLTs, firstly because it is a classification primarily intended to provide information for genetic research and secondly because the classification is applied following a detailed narrow-transcription of a connected speech sample of at least 200 utterances, and complex time-consuming coding procedures. This would be outside of the scope of time available to most clinical SLPs/SLTs.

In summary, a classification system based on aetiology alone is insufficient to subdivide children's speech difficulties. The SDCS (Shriberg et al., 1994; 2010) has been developed specifically to classify speech sound disorders of unknown aetiology. However, its main use currently is in genetics research and it is not yet in a form which makes it practical for clinical use. The ICF-CY has the advantage of including both body structures and functions which may be affecting a child's speech and furthermore it records the impact of the speech impairment on a child's ability to participate in everyday activities. Unfortunately, the current terminology for speech is limited to an umbrella term of "Articulation functions", and this limits its application as a differential tool.

1.6.2 Linguistic Classifications

SLPs/SLPs have been encouraged to think about children's speech difficulties in terms of patterns of sound class and phonological processes which occur in typical development, rather than as difficulties with individual speech sounds, for over forty years (see Bowen, 2015 for a historical review). Early 'phonological' approaches (e.g. Ingram, 1976; Grunwell, 1981) subdivided children's speech difficulties into 'delayed' (error patterns which occurred in typical development but at a younger age) vs. 'disordered' or 'atypical' (error patterns which do not occur in typical development). However, these phonological approaches have short-comings as classification systems for speech difficulties, since they only account for speech impairments occurring in the context of the child being able to articulate individual sounds well in isolation. In such cases, the child has no phonetic difficulty in producing speech sounds but has difficulties in using speech sounds to convey meaning. This suggests that their difficulties are arising within the cognitive-linguistic domain, rather than at a lower level of articulatory skill.

A more inclusive linguistic classification system for speech impairment needs to account not only for phonological difficulties, but also for phonetic difficulties with individual sounds. Phonetic errors (e.g. a lisp or lateral /s/) occur when a child has difficulty making specific speech sounds because of 'faulty habits of articulation' (Rvachew & Brosseau-Lapre, 2012). For some children, this is their sole speech difficulty. However, phonetic vs. phonological errors are not mutually exclusive (Gierut, 1998) and may indeed interact; some children will present with both types of speech difficulties and these need to be accounted for in any linguistic classification system intended for clinical use.

Dodd (1995; 2005) has produced a classification system for functional speech disorders (of unknown origin) which is based on surface speech errors and considers both phonetic and phonological difficulties. Within this classification system, subgroups of speech disorders are associated with a particular pattern of performance purported to arise from different underlying deficits (Ozanne, 2005). These subgroups have been identified in different languages (English, Cantonese, German, Spanish and Mandarin) and each is proposed to respond to a different treatment approach. Dodd et al. (2003) have supported their approach by collecting normative data from 684 British English-speaking children (aged 3;0-6;11) on age of acquisition for sounds (phonetic acquisition) and the age that error patterns were suppressed (phonemic acquisition). Dodd's (1995; 2005) proposed subgroups are:

Articulation disorder: an impaired ability to pronounce specific phonemes, usually /s/ or /r/. This phonetic difficulty is present when the target sound is produced in isolation as well as in words, and occurs in both imitated and spontaneous productions. The hypothesised level of deficit is described by Dodd and colleagues as learning of motor movements, phonetic planning or execution of smooth sequences of gestures.

Phonological delay (PD): characterised by phonological simplification patterns which occur in typical development, but in younger children. No particular level of breakdown in psycholinguistic processing is hypothesised. It may result from slow neurolinguistic maturation or impoverished input. Mild delays may not require intervention but children with more significant delays will.

Consistent phonological disorder (CPD): characterised by the presence of some non-developmental or unusual error patterns, such as 'backing' or 'initial consonant deletion'. Children who present with these atypical error patterns may also have some typical error patterns in their speech. Atypical error patterns are hypothesized to arise at the level of abstracting the rules that govern phonology and as a result such children have an impaired understanding of their native phonological system (Dodd, 2011).

Inconsistent phonological disorder (IPD)*:* speech shows a high level of variability (at least 40% of items will be produced differently on a picture naming task comprising 25 pictures administered on three separate occasions within one session). To be included in this subgroup, a child must demonstrate multiple error forms for the same lexical items, and not simply a correct and then incorrect version which might suggest a maturing phonological system. Dodd proposed that IPD occurs as a result of a phonological planning deficit i.e. a breakdown in phonological encoding.

Dodd (2005) suggests that 50-60% of children with functional speech impairments (of unknown origin) have delayed phonology and 25-30% make some atypical errors on a consistent basis. Of the remaining children, 10-12% have an articulation disorder and 10% present with IPD. However, a problem with a classification system like this that only includes speech impairments of unknown aetiology, is that it is not an inclusive system. For example, children who have speech difficulties as a result of a known cause (e.g. cleft palate, cerebral palsy, hearing loss) are excluded, even though their presentation may be similar, in most part, to those of children with speech impairments of unknown aetiology. Furthermore, children with a known cause may have additional speech difficulties, resulting from an unknown cause. For example, a child with a hearing loss who has a range of speech (and language) difficulties, some of which cannot be explained by the nature or level of the hearing loss. This issue was explored in a case-study by Ebbels (2000).

Rvachew and Brosseau-Lapre (2012), commenting on Dodd's classification system, note that although it is possible to classify children's speech errors into the four subgroups at a given time point, it has not been established that these categories remain stable over time. Stackhouse (1992) demonstrated this when describing the developmental speech difficulties of children with DVD which changed over time. Thus children may change from one subgroup (e.g. CPD) to another (e.g. PD), as a result of intervention and/or through maturation. Furthermore, Rvachew and Brosseau-Lapre (2012) suggest that the four subgroups may just reflect the age of the child and the severity of their speech difficulties, rather than distinct subtypes of speech disorder. With regards to severity, data produced by Dodd et al., 2005 (chapter 3), demonstrates an increasing scale of severity by subgroup in terms of Percentage of Consonant Correct (PCC) scores on the DEAP Phonology Assessment: Controls: 96%; PD: 77%; CPD: 60%; IPD: 44%. With regards to age, Broomfield and Dodd (2004) reported that different subgroups mainly occurred at different ages in their study of three hundred and twenty children, aged under 2 years to over 11 years, referred to a speech and language therapy service. For example: articulation disorder was commonly only assigned to children of 7 years and above, whereas IPD was assigned virtually always to children aged between 3 and 5 years. Thus, children who were making more unusual error patterns were clearly younger than those making more typical error patterns. Rvachew, Chiang and Evans (2007) reported a similar finding from their longitudinal study of fifty-eight children with a developmental phonological disorder who were assessed before kindergarten entry and at the end of their kindergarten year: error types changed with age and varied with severity: younger and more severely impaired children made more syllable structure (phonotactic) errors and more atypical errors than older and less severely affected children. Rvachew and Brosseau-Lapre (2012) concluded that:

> "Rather than being the hallmarks of phonological disorder, inconsistent and unusual matches to adult targets are the primary characteristics of very early phonological development. Certainly, the persistence of these behaviours signals the need for assessment and appropriate follow-up by SLPs, but they can be seen to exist on a developmental continuum with later emerging errors patterns" (p. 512).

A number of methodological concerns about Dodd's classification system were raised by Waring and Knight (2013). One of these centres around the Inconsistency Assessment, which requires a child to name 25 words (of varying syllabic complexity) over three trials in the same session. Performance on this subtest determines whether a child is classified as having consistent or inconsistent phonological disorder. Furthermore, when it is used in conjunction with the Oro-motor Assessment, it has a crucial role in differentiating between children who have DVD versus IPD. This is an important distinction to make since it has implications for service delivery, intervention goals and strategies, prognosis and family expectations (RCSLT, 2011). Waring and Knight (2013) advise that the validity of the Inconsistency Assessment has not been established and furthermore, it has not been determined that this is the best way to measure consistency within a child's speech. Other authors have proposed alternative measures of word consistency, such as rapid naming tasks (Preston and Koenig, 2011). In addition, different analyses have been used; for example, the Error Consistency Index (EC1) (Tyler et al., 2003), and the Total Token Variability (TTV) (Marquardt, 2004) to measure phonetic variability (consistency). A further concern raised by Waring and Knight (2013) is that all the studies published to date using the subgrouping classification have been produced by Dodd's own research group and have involved relatively small numbers of children. It is suggested that the classification system would be strengthened if other research groups conducted studies and found similar results and if larger numbers of children were included.

In summary, the linguistic perspective has significantly shaped the ways in which SLPs/SLTs think about children's speech difficulties and has provided the terminology to describe speech difficulties in detail, which is helpful both for differential diagnosis and when planning treatment targets. However, surface error patterns can occur for different reasons between children and even within an individual child (e.g. Stackhouse and Wells, 1993), and a linguistic approach cannot provide underlying explanations for speech processing breakdown.

1.6.4 Psycholinguistic Classifications

Psycholinguistic approaches to classification have been described as providing a bridge between aetiological (medical) classifications and linguistic descriptions (Kamhi, 1989). They aim to explain how children process speech at a psychological level and to formulate hypotheses about the psychological processes and components that may be impaired.

Theoretical psycholinguistic models have been developed in order to account for the processes and stages involved in speech production. Apart from some computational models (e.g. the DIVA model, Guenther, 2006), there has been little attempt to locate specific processing levels in the brain or to explain how processes work at a neuro-physiological or biomechanical level, particularly in children. Instead, psycholinguistic models typically attempt to represent levels of processing via boxes, and processing routes via arrows connecting the boxes. Such box-and-arrow models can provide a framework for identifying the level(s) at which there might be a breakdown in speech processing, as well as providing clinicians with a tool to identify an individual child's profile of speech processing strengths and weaknesses (Stackhouse & Wells 1993; 1997). Some models have also been used to identify the aetiology of particular types of speech difficulties.

The same principles apply when using a psycholinguistic approach, regardless of which particular model is used: a set of hypotheses are developed and systematically tested to find out where the speech processing breakdown is occurring. The approach is inclusive, since it can be used to investigate the speech difficulties of any child, regardless of whether or not there is a known cause. There is no attempt made to subdivide children into different subgroups with descriptive labels; instead in this approach, a focus is given to identifying an individual child's speech processing profile of strengths and weaknesses, which can then be used to plan appropriate intervention.

Dodd (1995) suggested that the following three major aspects are the basis for a speech processing model: (a) receptive processing of words; (b) the storage or underlying representations of words; and (c) the processes involved in word production. A number of different psycholinguistic models exist and Baker et al. (2001) advised that the main differences between models centre around: (1) whether they include a single lexicon, which stores input and output representations or whether they include separate input and output lexicons; (2) the complexity of the processing stages in the input and output channels of the speech processing chain; (3) whether they include offline (not in real-time) processing as well as online (in real-time) processing. In this review, three theoretical models will be considered in detail: (a) the *Cascade Model of Speech Output Planning and Programming* (Ozanne, 1995; 2005) which focuses on speech output, (b) The *Psycholinguistic Speech Processing Model* (Stackhouse & Wells, 1997) which accounts for both input and output processing, and (c) *The*

Developmental Phase Model for Speech and Metaphonological Awareness (Stackhouse & Wells, 1997).

1.6.4.1 Cascade Model of Speech Output Planning and Programming (Ozanne, 1995; 2005)

Ozanne's model (1995; 2005) addresses the processing which takes place between phonological (realization) rules and motor execution in the psycholinguistic model proposed by Duggirala and Dodd (1991). Although the cascade model is essentially a boxes and arrows model, it is represented in a flowing and cascading diagrammatic form. There are three boxes which represent the three key levels of processing: (a) the phonological plan, (b) the assembly of the phonetic programme and (c) the implementation of the motor-speech programme. The arrows represent the flow-on and feed-back effects that deficits from other levels may have on each other.

At the level of the phonological plan, the child selects segments and sequences them together to create a phonological plan for the word or utterance to be spoken. Ozanne (1995) hypothesised that a number of deficits could occur at this level, including: there is no plan (i.e. it cannot be assembled on-line, it has not yet been learned or it has not been stored); the plan is under-specified or is incorrect; the plan cannot be accessed; the structure of the plan is influenced by the linguistic load. The resulting clinical speech behaviours could include: inconsistent productions, increased errors with increased performance load, phonotactic errors, and phoneme sequencing errors, including metathesis. Furthermore, some signs of language difficulties may also result from deficits at this level, e.g. word-retrieval problems could occur if the child has difficulty accessing previously learned plans. In addition, syntactic errors and prosodic disturbances may occur since phonological planning includes planning of strings of words, including supra-segmental features such as stress and intonation.

At the phonetic programme assembly level, the linguistic plan is translated into a motor programme. A deficit at this level would result either in no phonetic programme being devised or one that is incorrect or under-specified. The resulting clinical speech behaviours would include: omissions (because the full phonetic programme is not available) and/ or substitutions (because an alternative phonetic programme is devised, which may share some salient features with the target). It is possible that a type of articulation disorder as well as articulatory dyspraxia[5] arise due to a breakdown at this level of processing. In the case of an

[5] articulatory dyspraxia is the term used by Ozanne (1995) for DVD.

articulation disorder, the child usually responds well, once they are shown how to assemble a new motor programme during speech and language therapy. In contrast, children with articulatory dyspraxia have difficulty assembling new phonetic programmes easily and thus struggle to learn new sounds and words. Similarly, their progress in speech and language therapy tends to be slow as they try to move from one step to the next. Clinical speech behaviours which arise at this level include: differences between voluntary and involuntary performance, groping on isolated speech sound production and/or on word production, saying words spontaneously but not being able to imitate them or use them again, using speech sounds in words but not being able to imitate those sounds in isolation, and producing sounds in words but not necessarily in the appropriate context.

At the oral and speech-motor programme implementation level of processing, the phonetic programme has to be executed. This will be affected by structural limitations (e.g. cleft palate) or reduced oro-motor abilities (e.g. dysarthria, oro-motor dyspraxia, or immature oro-motor skills) as well as by speech-motor abilities. This level of processing appears to be similar to the sensori-motor programming stage of Caruso and Strand's (1999) model of motor speech disorders, in which articulatory timing and positioning are determined. Schmidt and Lee (1999) state that although the correct motor programme may be chosen, errors can still occur because the wrong timing and force parameters are selected, resulting in speech sound distortions. Ozanne (2005) suggested that the resulting types of articulation disorders may not respond well in therapy and can be considered to be motor-programming disorders (Hall, 1989). Other errors which may arise at this processing level include: phonetic errors (e.g. voicing errors), resonance inconsistency and phonetic variability. All of these errors are indicative of difficulties with the simultaneous fine motor co-ordination of the various speech subsystems involved. Poor fine motor co-ordination may also be the underlying explanation for difficulties shown on DDK tasks, including slow rates, inability to maintain correct sound sequence and dysrhythmic productions.

Ozanne (1995; 2005) considered how her model could help when trying to make a differential diagnosis of DVD/CAS. She suggested that some children would have deficits at all three levels (phonological planning, phonetic programming and motor-programming implementation), while other children may not. However, for a diagnosis of DVD/CAS to be made, they must show difficulties with the two motor levels of the model specifically, i.e. phonetic programming, and oro-motor and speech motor-programming implementation. Children who only have difficulties in formulating a phonological plan are more likely to have a phonological/linguistic deficit and be identified as having an inconsistent phonological disorder (Dodd, 1995; 2005).

1.6.4.2 The Psycholinguistic Speech Processing Model (Stackhouse & Wells, 1997)

According to Waring and Knight (2013), the psycholinguistic model which has had most impact on clinical speech and language therapy is that proposed by Stackhouse and Wells (1997). It comprises a single-lexicon box-and-arrow model, with multiple levels identified between audition and motoric production, and includes both online and offline processing. This approach has been effective in linking speech processing theory to assessment and to therapy approaches used in clinical practice.

The *Psycholinguistic Speech Processing Model* (Stackhouse & Wells, 1997) is based on the premise that speech processing involves the routing of information between ear, stored representations and mouth (see Figure 1). There are two information channels: speech information is received and decoded on the input side, and encoded and transmitted on the output side. In addition, there is a store of lexical representations which include details of a word's meaning (semantic representation), sound structure (phonological representation), instruction for articulation (motor program), grammar, as well as orthography (reading and spelling) in school-age children. These representations serve as a basis for recognising speech as well as generating speech output. In addition, speech information may be routed in a top-down direction by utilising stored information, and/or in a bottom-up direction by utilising peripheral sensory input, in order to perform a task.

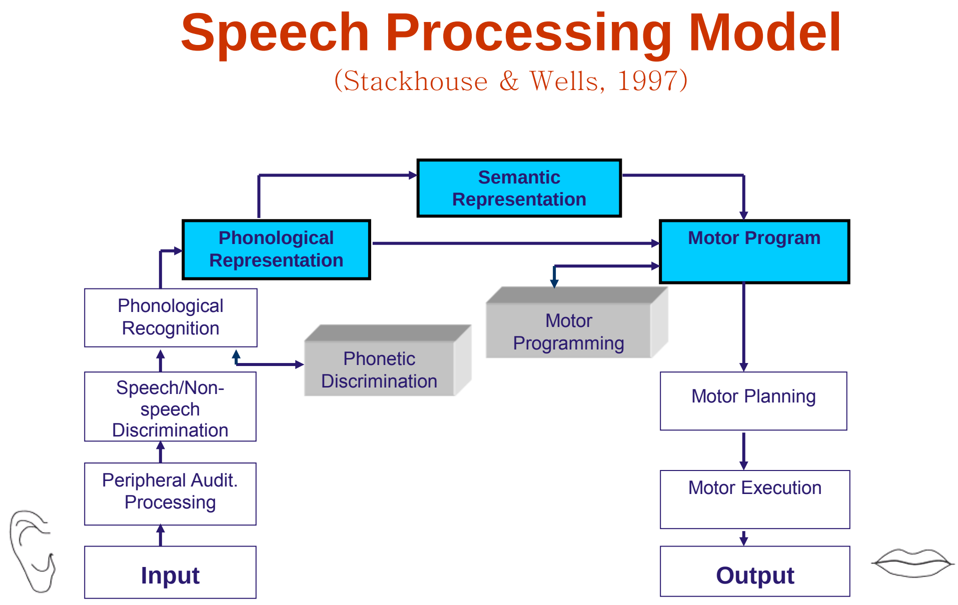


Figure 1.1 Box-and-arrow Speech Processing Model (Stackhouse and Wells, 1997).

There are three central tenets of the approach: (1) typical speech development relies on a normal functioning speech processing system; (2) children with speech difficulties have a breakdown in speech processing at one or more points in the speech processing chain; (3) speech difficulties can be remediated by using strengths in the speech processing system to target 'faults' in speech input, representational and output levels. The following levels of processing are included in the *Psycholinguistic Speech Processing Model* (Stackhouse & Wells, 1997).

Input

Peripheral auditory processing – hearing acuity is a necessary first stage in processing the speech signal. This is the first level where breakdown could occur in the speech processing chain and therefore information concerning a child's peripheral hearing is crucial when evaluating a child's speech difficulties.

Speech/non-speech discrimination – recognition that the incoming signal is speech vs. non-speech.

Phonological recognition – recognition of the speech signal as belonging to a familiar language, as well as being able to segment the speech signal into words and then individual phonological units. Word and non-word same/different judgement tasks tap processing at this level.

Phonetic discrimination – required to deal with novel phonetic material, e.g. from an unfamiliar accent or language, or some routine therapy tasks, e.g., asking a child to discriminate at a phonetic level between sounds s/he substitutes e.g. [ɬ] for [s] – "did you hear a hissing sound or a slushy sound?"

Lexical representations

Phonological representation –part of the lexical representations, stored along with semantic, grammatical and orthographical representations. It includes the information necessary to discriminate between similar sounding words (e.g. 'cap' as distinct to 'tap') and to identify a word when produced by a range of speakers. Information is likely to be stored hierarchically in terms of syllable, onset and rime, nucleus and coda, with phonemes specified by distinctive features. The accuracy of phonological representations can be checked using real word discrimination tasks and picture stimuli such as in mispronunciation detection tasks where child sees a picture (e.g. of a fish) and hears either the correct or incorrect pronunciation of that picture spoken by the tester (e.g. 'Is this a /fɪs/?). Further detail of such tasks can be found in the *Compendium of Auditory and Speech Tasks* (Stackhouse et al., 2007)

Motor program - part of the stored lexical representations. It contains a series of gestural targets for the articulators (lips, tongue, palate, vocal folds), designed to achieve an acceptable pronunciation of the word, which matches the stored phonological representation. This processing level is involved in picture naming and word repetition, including DDK tasks which require the child to repeat a familiar real word target (e.g. PAT-A-CAKE).

Output

Motor programming - off-line level of processing involved in early sound production and babbling and is crucial in early language development in creating and refining motor programs for a rapidly expanding vocabulary. It continues to be important after the basics of speech are established in creating motor programs for new words that are experienced. It is thought to contain a store of phonological units, probably onsets and rimes rather than individual phonemes, which can be combined to create new motor programs for unfamiliar words. This processing level is involved in non-word repetition, including DDK tasks which require the child to assemble and repeat a non-word target (e.g. [ˈkudægn]).

Motor planning - Once a motor program has been retrieved or a new one created, a plan for the utterance is formed. This involves assembling the gestural targets in the correct sequence, and taking account of the intended grammatical structure, phonetic environment and prosodic features such as rhythm, rate, stress and intonation. This processing stage is easier to illustrate for utterances longer than single words. DDK tasks which require a target to be repeated several times involve motor planning skills.

Motor execution - At this level, the motor plan is actually executed and this gives rise to an acoustic signal. It includes all the physical organs involved in producing speech, including the lungs, the larynx, oral and nasal cavities, lips, teeth, tongue, and palate. This processing level is involved in ore-motor tasks, production of speech sounds in isolation and DDK tasks which require the child to repeat a syllable sequence with no syllable stressed more than any other (e.g. [lətəbə]). Anatomical problems with any part of the vocal tract (e.g. as in cleft palate) may result in difficulties with speech production. Similarly, if there is damage to the nerves which innervate the above structures, as in dysarthria, speech production is also likely to be affected.

Self-monitoring – to complete the process, the child should be able to monitor his speech, identify errors by comparison with stored phonological representations, and make an attempt to correct them.

According to Waring and Knight (2013) there is a strong theoretical underpinning as well as clinical evidence from a number of perspectives to support the validity of Stackhouse and Wells' (1997) model. Specific speech processing deficits have been identified through a longitudinal group study of forty-seven children with speech difficulties, aged 4-6 years (Nathan et al., 2004) and from individual case studies from the cohort of children with speech difficulties (Stackhouse et al., 2007). In addition, both quasi-experimental case studies (Pascoe et al., 2005; 2006) and non-experimental case studies (e.g. Corrin, 2001; Nathan and Simpson, 2001; Rees, 2008) have demonstrated the validity of this approach in treating children's speech and literacy difficulties (Williams, McLeod, Mc Cauley, 2010). However, Waring and Knight (2013) also suggest there may be some theoretical shortcomings of the psycholinguistic approach. First, breakdowns in speech processing are restricted to input and output mechanisms, but they could be arising from a more central level e.g. the learning of phonological constraints (Dodd, 2005). Second, deficits are treated as the cause of a child's speech difficulties, whereas they could be a consequence or co-morbid symptom of another underlying deficit. For example, Zelazo and Muller (2002) and Dodd (2011) argue that higher order executive functioning can impact on the speech processing chain. Third, the proposal that each child has a unique profile of speech processing strengths and weaknesses limits its predictive value in terms of how a child might change over time or change in response to treatment. However, further evidence from more single case treatment studies could increase the predictive validity of the approach and a trend in strengths and weaknesses at different phases could emerge. Fourth, if individual clinicians use different assessment tasks, this could lead to different diagnoses being made and thus affecting the reliability of such an approach.

The box-and-arrow *Speech Processing Model* (Stackhouse & Wells, 1997) was developed to aid understanding of children's typical and atypical processing skills and was not intended originally to be used as a classification tool to subdivide children with speech difficulties. However, the psycholinguistic framework (Stackhouse & Wells, 1997) includes a further theoretical model, the *Developmental Phase Model*, and Waring and Knight (2013) suggest this model could be used as a classification tool for children's speech difficulties.

Box-and-arrow models are often criticised when used with children because they cannot reflect developmental change over time (Stackhouse and Wells, 1996). The *Developmental Phase Model* was created to account for how typically-developing children develop speech between the ages of 0-5 years. It can also be applied to children whose speech is not developing typically. Such children will have difficulty at one or more phases of the model. This difficulty manifests as slow or troublesome progress through a phase compared to typically developing children. In severe cases a child's development may be described as 'arrested' at a particular phase. The model comprises five phases: pre-lexical, whole word, systematic simplification, assembly and metalinguistic phases, and each is described briefly below.

Prelexical Phase

This phase describes the period pre-the development of first words. During this first year of life, typically-developing children develop motor control over their vocal tracts and simultaneously develop their vocal skills starting with basic cries, before moving onto vowel-like vocalisations, and then to the onset of canonical babble and subsequently variegated babble.

The child's ability to pass through this phase will be impaired if there is any anatomical problem within the vocal tract, e.g. cleft lip and palate, or if there is damage to the muscles themselves, as in muscular dystrophy, or to the nerves which innervate the muscles, as in cerebral palsy. Any problem at the peripheral level on the input side of the model, such as a hearing loss, will also affect a child's ability to pass through the Prelexical phase, even though they have no anatomical or neurological problem on the output side.

Whole Word Phase

This phase describes the period following the Prelexical phase in which first words are produced (as whole units), between 1 and about 2 years of age. During this phase, the speech of typically-developing children is characterised by limited consonant and vowel sound repertoires, a reduced range of syllable structures and a high level of inconsistency.

Stackhouse and Wells (1997) proposed that children with word-finding difficulties as well as those with DVD may be arrested at this whole word phase. Children with DVD commonly produce highly simplified word forms, have limited speech sound inventories and sequencing difficulties and demonstrate inconsistency in their speech production (ASHA, 2007; RCSLT, 2011).

Systematic Simplification Phase

A typically-developing child enters this phase towards the end of the second year of life and continues to move through it during their third and fourth years. This phase is characterised by the emergence of phonological simplification processes, such as fronting, stopping, and cluster reduction, with the child now demonstrating consistent speech production.

Stackhouse and Wells (1997) proposed that children described as having phonological delay or phonological disorder have difficulties at the Systematic Simplification Phase.

Assembly Phase

This phase covers the period from around 3 to 4 years of age in which typically-developing children develop control over more complex articulatory sequences, such as affricate sounds, consonant clusters and polysyllabic words, in addition to mastering production of connected speech. This is the phase where children learn strategies to join words together at word-boundaries and master their intonation and fluency skills.

Stackhouse and Wells (1997) proposed that stammering and prosodic difficulties arise due to difficulties in this developmental phase.

Metaphonological Phase

Typically-developing children generally enter the Metaphonological Phase during their 5th year (Stackhouse & Wells, 1997). By this stage, most typically-developing children have intelligible speech, although they continue to develop their competence in using complex consonants and word shapes, as well as strategies for producing fluent, cohesive connected speech produced with appropriate intonation patterns. Typically-developing children are now ready to start developing their early literacy skills.

Stackhouse and Wells (1997) suggested that children who have literacy acquisition difficulties and those with dyslexia are arrested at this developmental phase, and they demonstrate how their phase model of speech development and difficulty can be mapped onto Frith's (1985) phase model of literacy development.

In their review, Waring and Knight (2013), suggest that the *Developmental Phase Model* could be used as a classification tool, by subdividing groups of children with speech difficulties by the phase which most accurately describes their functioning, at a particular time point. This encapsulates the notion that children change and may not comfortably fit or remain in one subgroup of speech difficulty. However, the phases themselves may not be so clear cut in real life situations and only children with severe speech difficulties will be truly 'arrested' within a specific phase. For other children, different aspects of their speech difficulties may fit into several different phases and this is likely to limit the practical use of this approach with clinical cases.

In summary, different theoretical psycholinguistic models have been proposed to account for the processes and stages involved in speech production, including a model which reflects developmental change in young children's speech acquisition. There has been some attempt to use models as classification tools, to subdivide children's speech difficulties, and this has been illustrated in experimental case studies (e.g. Pascoe et al., 2006). Further research is needed to demonstrate their application to group studies.

1.7 Summary of Main Findings from Chapter One

Medical, linguistic and psycholinguistic approaches have been developed and applied to the classification of children's speech difficulties. There are advantages and disadvantages to each of these three approaches and furthermore there are similarities, as well as differences between them. However, there is still no consensus agreement over the best approach to use and therefore classification remains an unresolved issue in speech pathology. There is still a need to develop a classification system that has universal support:

> “.....to facilitate communication between professionals and researchers and allow further testing of diagnostic and treatment hypotheses” (Taylor, 2011).

The literature review indicates that typically-developing children become faster, more accurate and more consistent in DDK production with increasing age and speech motor maturity. In contrast, studies have shown that children with speech difficulties find DDK tasks challenging. However, there are still relatively few published studies of DDK performance by children with speech difficulties, and those studies which are available have included children of differing ages, and with varying types and severities of speech difficulties. Furthermore, there is often limited information available about the exact nature of the children’s individual presenting speech difficulties, although there is some evidence that it may be children who have articulatory rather than phonological difficulties who experience particular difficulties on DDK tasks. It remains debatable whether DDK tasks can be used to differentiate the motor speech disorder DVD from other types of speech difficulties. Case study evidence has suggested that children with speech difficulties present with differing DDK profiles, in terms of accuracy, consistency and rate, and that these profiles may be associated with specific types of speech sound disorders. Thus, although it may be possible to subdivide a cohort of children by their DDK performance, this concept needs further investigation with a larger group of children.

Chapter Two

Literature Review 2

Speech Motor Development and Assessment of Speech Skills

2.1 Introduction to Literature Review 2

In Chapter One, studies of DDK performance of typically-developing children and those with speech difficulties were reviewed, and the classification approaches which have been applied to children's speech difficulties were examined. The literature review will continue in chapter two with a review of typical and atypical speech motor development in children and how this relates to the development of DDK skills. This is followed by a review of investigations and assessment procedures which have been applied to children's speech skills. As part of this, a critique of task design, measurements, and procedures which have been used to investigate DDK skills will be presented. Finally, the research questions for the current study will be listed, which have been formulated in the context of the literature reviews in chapters one and two.

2.2 Typical and Atypical Speech Motor Development

DDK is considered to be a measure of speech motor skill. Speech motor control develops gradually from birth, with the child increasingly gaining co-ordinated control over respiratory, laryngeal and articulatory subsystems, involving over one hundred muscles (Kent, 2004). Although the majority of key speech motor development takes place in the early years of a child's life, fine-tuning and refinement of motor skills continues over many years and current evidence suggests speech motor control is not fully adult-like until at least 16 years of age (Walsh & Smith, 2002). Hallmarks of competent speech motor skills include precise articulatory accuracy, consistency of articulatory movement, efficiency of articulatory movement and speed of production (Fletcher, 1992).

2.2.1 Typical speech motor development in the first year of life

Babies are born with highly developed speech perception, but limited oral motor control and a restricted repertoire of vocalisations (Rvachew & Brosseau-Lapre, 2012). During the first year of life, typically-developing children develop motor control over their vocal tracts and simultaneously develop their vocal skills, from basic cries, to vowel-like vocalisations, to the onset of canonical and then variegated babble. In the early months, babies develop control of their voice, demonstrating integration of respiratory and laryngeal subsystems, and then from around 6 months of age, the articulatory subsystem (jaw, lips, tongue, palate) develops and is increasingly integrated with the laryngeal and respiratory subsystems. An important milestone is the development of canonical babbling at around 6-7 months of age. Canonical syllables, which form the basic phonetic building blocks of all adult-languages, consist of at least one vowel-like sound and one consonant-like sound, with smooth rapid transition between the two elements. Canonical babbling usually includes stop, nasal and glide consonants made at the labial and coronal places of articulation and non-rounded vowels in simple CV and CVCV syllable shapes, which are repeated rhythmically in strings.

Studies have shown strong links between the development of babble and the development of first words. Children who demonstrate favourite babbles and consistent vocal motor patterns at the expected time tend to develop words earlier than children who have delayed babble (McCune & Vihman, 1987). Variegated syllable sequences, involving consonant and vowel changes, for example /ba-da/, may emerge simultaneously with canonical babbling or soon after it and become more frequent towards the end of the child's first year.

In the later months of the first year, the babble of hearing babies is increasingly influenced by the speech sounds of their language environment. Vihman (1996) described this as the "Babble drift hypothesis" whereby infant vocalisations move from a universal pattern to reflect more closely the sounds of the ambient language. Language-specific prosodic patterns gradually also emerge between 6 -12 months of age, simultaneously with the development of babble.

Before moving on to consider atypical development, it is important to consider current evidence concerning the relationship between oral motor development and speech motor development in the first year of life. There is increasing evidence of oral motor control for feeding being separate from motor control for vocalisation early in life (Moore & Ruark, 1996). Furthermore, motor control for breathing at rest is separate from breathing for speech (Moore et al., 2001). Studies have shown that non-speech oral behaviours and speech involve separate co-ordinative structures which develop in parallel but along divergent paths (Steeve et al. 2008; Rvachew & Brosseau-Lapre, 2012). It is therefore not the case that speech develops from established controlled oral motor movements for feeding. Green et al. (2000) argued that if anything, there is a negative rather than positive influence of movement patterns established for feeding on the infant's early attempts to co-ordinate their articulators for speech production. Labio-mandibular patterns established for feeding require tight linking of lips with jaw in a highly rhythmic stereotyped pattern; in order to produce syllabic vocalisations with varied prosodic contours, the infant has to overcome these interdependent inflexible patterns. In general, speech requires finer levels of co-ordination (Green et al., 2000) but lower levels of strength than for other oral motor activities (Forrest, 2002; Clark, 2010). The muscles involved in speech are from five different subsystems and are unique in the body (Kent, 2004). They are specialized for the precise co-ordination of complex movement sequences at a rapid rate.

Thus, the studies above indicate that oral-motor control and speech motor control are independent functions, despite involving similar structures.

2.2.2 Atypical speech motor development in the first year of life

The first year of life is covered by the Pre-lexical Phase in the *Developmental Phase Model* (see Chapter One, 1.6.4.2) (Stackhouse and Wells, 1997). The child's ability to pass through this phase successfully will be impaired if there is any anatomical problem within the vocal tract or if there is damage to the muscles or to the nerves which innervate the muscles. In terms of speech processing, this will affect motor execution - the stage at which the motor plan is executed and gives rise to the acoustic signal. Thus, a structural abnormality such as cleft lip and palate will impact on speech acquisition from birth, although the effect will be mitigated in many children, provided surgical repair takes place in early life and is successful. In contrast, the outcome for children with muscular problems, such as muscular dystrophy, or with neurological damage, such as cerebral palsy resulting in developmental dysarthria, is not so positive, as no repair is possible.

Any problem at the peripheral level on the input side of the model will also affect a child's ability to pass through the Prelexical phase, even though they have no anatomical or neurological problem on the output side. A hearing loss impairs the child's speech perception and is known to have a significant effect on the development of babbling. Deaf babies are reported to start babbling later than babies with normal hearing. Furthermore, they may start to babble but then stop and/or to have a restricted repertoire of consonant and vowel sounds within their babble. The effect of a hearing loss prevents the child from developing sounds which are specific to the ambient language, and therefore the deaf child's speech acquisition in the later part of the first year becomes increasingly different to that of a typically-developing child.

Babies, with normal hearing and no anatomical abnormalities, who have not developed canonical babbling by around 10 months of age, are at risk of having speech and language difficulties. For example, Oller et al. (1999) reported that children who babbled late had smaller expressive vocabularies at 18, 24 and 30 months than children who developed babble at a typical age of 6-7 months. Failure to babble or late onset of babbling is also considered to be a ‘red flag’ for speech impairment and is particularly associated with motor speech disorder (Bowen, 2015).

Highman el al. (2008) investigated the early vocal behaviours of children with suspected CAS (sCAS). They asked parents of 20 children, with a mean age of 7; 6 to complete a retrospective questionnaire on early vocal behaviours and compared their responses to those given by parents of 20 typically-developing children, with a mean age of 11;3. Highman et al. (2008) reported that as a group, children with sCAS were less vocal, later in developing babble and slower in producing first words and two word combinations, than the typically-developing controls. It was common for parents of children with sCAS to report that their children had not babbled at all or had achieved canonical, but not variegated babble. Highman et al. (2008; 2012) proposed that the above findings supported the view that children with CAS have speech motor impairments, which impact on their ability to develop early vocal behaviours. This puts them at a disadvantage in terms of establishing articulatory patterns to couple with lexical concepts for first word production (Maassen, 2002).

Further evidence of babbling difficulties in children with CAS, has been demonstrated in a small scale study reported by Overby and Caspari (2013). Using home videos provided by the children’s parents, they compared the early vocal development of four children diagnosed with CAS between the ages of 3 and 5 years to that of two typically-developing children in the same age range. The findings confirmed anecdotal parental reports of children with CAS being silent babies; the four children’s average number of utterances over a unit of time was between one fifth to one third of that of the typically-developing children. Further, the babble of the children with CAS had reduced syllable shapes, comprising predominantly of vowels and CV syllables rather than CVCV productions, and showed a place preference for bilabial and alveolar consonant sounds, and a manner preference for stops and nasals.

The findings of the studies by Highman et al. (2008) and Overby and Caspari (2013) have a relevance for DDK studies of children with CAS. Repetition of mono-syllables e.g. as reported in the studies of Thoonen et al. (1996; 1999) resembles canonical babbling whereas repetition of tri-syllables involving different phonetic placements of each onset consonant e.g. as reported in the studies of Yoss and Darley (1974); Lewis et al.(2004) and Murray et al. (2015), resembles variegated babbling. It seems plausible that the children's reported difficulties on DDK tasks may be related to their limited experiences with canonical and/or variegated babble.

2.2.3 Typical speech motor development during the second year of life

From around 12 months of age, children move into the phase in which first words emerge. They also produce a range of other spoken output including: babble, with more variegated patterns emerging and a wider diversity of consonants and vowels included in their babble; jargon -strings of connected sounds produced with appropriate intonation, which sounds like language, but is in fact meaningless, and symbolic sounds, such as animal, vehicular and expressive sounds, which they use to represent words.

At this stage, described by Stackhouse and Wells (1997) as the Whole Word Phase in their *Developmental Phase Model* (see Chapter One, 1.6.4.2), the child has to develop articulatory skills, which depend on ongoing physical maturation and refinement in co-ordinating the movements of the vocal tract, and also are influenced by the nature of the early motor programs being stored in their representations. The child's ability to produce spoken forms is still limited by their motor execution capacity, however during this second year, the child gains motor control firstly over the jaw, and then over the lips and tongue, with the latter becoming increasingly differentiated from the jaw. Vocal practice and neuro-motor maturity both contribute to the formation of specific neuronal pathways for finer levels of control over the articulators.

Early motor programs are stored as whole units (gestalt) of undifferentiated gestures (Kent, 1992; Stackhouse & Wells, 1997). This results in highly simplified word forms being produced at this early stage. It also results in variability of production as the child struggles to co-ordinate articulatory gestures in order to realize the motor program at the motor execution level in a consistent way.

There is gradual development of vowel and consonant repertoires throughout this period. Early consonant sounds used are labial and coronal stops, nasals and glides, so typically the system includes: /p, b, t, d, m, n, w, j/. The child combines consonants (C) and vowels (V) together into phonotactic structures, mainly consisting of single syllable CV structures e.g. [mi] for ME; [dʌ] for DUCK; [bʌ] for BUS; and bi-syllabic, reduplicated CVCV structures e.g. [mama] for MUMMY; [baba] for BABY; [dada] for DADDY.

2.2.4 Atypical speech motor development in the second year of life

Stackhouse and Wells (1997) hypothesised that children with DVD may be 'arrested' at the Whole Word Phase and persist with early speech motor behaviours well past the age that they usually occur in typical development. For example, Velleman (1994) proposed that CV syllables, which can be articulated without changes in lip or tongue configuration, are common forms in the speech of children with DVD. Such syllables involve labial consonants combined with low and neutral vowels, alveolar and dental consonants combined with high front vowels and/or velar consonants combined with high back vowels. The child's difficulty with motor control results in them simplifying the structure as much as possible and relying on gross jaw movement rather than differentiated tongue and lip movements.

2.2.5 Typical speech motor development 18 months to 3 years of age

At this stage, which Stackhouse and Wells (1997) described as the Systematic Simplification Phase of their *Developmental Phase Model* (see Chapter One, 1.6.4.2), there is completion of the vowel repertoire and rapid expansion of the consonant repertoire, to include stops made with velar placement, fricatives and the liquid /l/. Furthermore, the complexity of word shapes the child can produce develops to include CVC and CVCVC structures. The hallmark of this phase is that the typical child's speech becomes more consistent through the use of identifiable simplification processes. Early simplification processes which occur at around 18 months of age are syntagmatic (affecting syllable structure), and include: reduplication of a syllable, instead of producing a change of consonant and/or vowel in the second syllable, for example: [wawa] for WATER; consonant harmony, in which one consonant has strong influence on the other leading to the same consonant being used in both syllables e.g. [ɡɒɡi] for DOGGIE; and final consonant deletion, in which the final consonant of the word is omitted e.g. [dʌ] for DUCK. As the child moves through this phase, it is common for earlier developing consonant sounds to be used as substitutions for later developing consonant sounds, which the child cannot so easily produce due to their limited motor capacity. Therefore, paradigmatic (affecting sound segments) simplification processes occur, for example, (a) fronting of velar stops, whereby /k/and /g/ are realised as alveolar stops [t] and [d], and (b) stopping of fricatives, in which consonants produced via a strong contact of two articulators released as a plosive, e.g. /p, b, t, d, k, ɡ/ replace those which require a finer contact to produce a fricative, e.g. /f, v, θ, ð, s, z, ʃ, ʒ/. These substitution patterns tend to affect the clarity of children's speech, with gradual improvements occurring as they mature. At 2 years, they are around 26-50% intelligible, whereas by 3 years, they are 71-80% intelligible (ASHA, 2007).

2.2.6. Atypical speech motor development from 18 months to 3 years of age

Children described as having phonological impairment, whether this is delayed or disordered, have difficulties at the Systematic Simplification Phase of development (Stackhouse & Wells, 1997, see Chapter One, 1.6.4.2). Traditionally, children assigned these labels are thought to have cognitive-linguistic difficulties, rather than speech motor difficulties (Dodd, 1995; Bradford &Dodd, 1996: Dodd & McIntosh, 2008). However, as Stackhouse and Wells (1993; 1997) explain this may be somewhat of a simplistic view as there are likely to be different psycholinguistic origins accounting for different simplification processes and there is likely to be variation in how this manifests itself in individual children.

2.2.7 Typical speech motor development 3 to 4 years of age

At this stage, which Stackhouse and Wells (1997) described as the Assembly Phase of their *Developmental Phase Model* (see Chapter One, 1.6.4.2), the child has to reconcile their still immature motor skills with the phonological demands of more complex sentences that they want to say. Children usually enter this phase around their fourth year and require motor planning skills to pass through this phase successfully.

In this phase, there is still change occurring within the typical child's consonant system, with more regular usage of velar stops and fricative sounds emerging. Complex articulatory sequences such as post-alveolar affricates /tʃ/ and /dʒ/ also begin to occur, which involve co-ordination of articulatory gestures for a stop followed by a fricative at the same place of articulation. Other complex articulatory sequences such as consonant clusters emerge resulting in additional word shapes: CVCC(C) and CVC(C) as well as polysyllabic words. In this phase, typically-developing children also gain control over the use of stress and intonation, specific to the language they are using. Furthermore, they learn strategies to join words together in connected speech:

> "In connected speech, children need to develop strategies for joining words together at word-boundaries in order to ...'glue' the utterance together into a cohesive entity" (Stackhouse & Wells 1997, p 226).

Strategies include the use of a /j/ or /w/ to help join a word that ends in a vowel to one that begins with a vowel e.g. DADDY IS TALKING produced as [ˈdadɪ jɪz tɔkɪŋ]; GO IN THE HOUSE produced as [ˈgəʊ wɪn ðə hɑʊs]; and assimilation of plosive consonants, whereby the final consonant of one word is not released but is assimilated to the place of articulation of the second consonant e.g. TWO SAD CATS produced as [ˈtu sag̚ kats].

Typically-developing speakers may make occasional 'slips of the tongue', for example, when a segment from one word is exchanged for a segment from another word e.g. "Boy and Jill" for BILL AND JOY. They also often produce pauses, reformulations and word searches as well as repetitions of words and phrases, demonstrating difficulties in assembling all the components of speech. Despite still making such errors in their speech, many children have consistent speech and are 100% intelligible to listeners by 4 years of age (Bernthal, Bankson & Flipsen, 2009).

2.2.8 Atypical speech motor development 3 to 4 years of age

Children who demonstrate difficulties with production of more complex articulatory sequences, such as affricate sounds, consonant clusters and polysyllabic words, have ongoing speech motor immaturity. Children who have persisting difficulties with fluency (pauses, reformulations, word searches, repetitions of words and phrases) may develop stammers at this phase. Some of the difficulties shown by children with DVD may also arise at this phase e.g. poor prosodic control and difficulties in learning word-joining strategies. Children with DVD have been reported to sound monotonous, as they show poor use of intonation and may use unusual stress patterns for their specific language e.g. producing excess-equal stress, whereby all syllables are given equal stress, rather than the typical stress pattern of English (ASHA, 2007). Furthermore, children with DVD also struggle with the use of junction and persist in producing words as separate single units rather than joining them smoothly into connected utterances.

2.2.9 Typical speech motor development 4 to 5 years and beyond

By this stage of development, most typically-developing children have intelligible speech, but they continue to develop their competence in using complex consonants and word shapes, as well as strategies for producing fluent, cohesive connected speech produced with appropriate intonation.

At this age, motor skills are still immature, but are gradually being fine-tuned and refined. As neuromotor control for speech increases, it is reflected in increased consistency of temporal and spectral features, increased ability to adapt to and compensate for external factors and increased speed of production (Waters, 1995).

In their *Developmental Phase Model*, Stackhouse & Wells (1997) described the Metaphonological phase, which typically-developing children enter during their 5th year, in which they start school in the UK. At this point, their speech and phonological awareness skills should be sufficiently developed so that they are ready to understand the mapping of sound to letter rules in order to develop their early literacy skills.

Research evidence suggests that full motor control for speech continues to be acquired gradually over many years. Typically-developing children continue to have speech which is more variable, less flexible, less accurate and slower than that of adults well beyond the pre-school period. For example, in a longitudinal study of articulation rates, involving 16 typically developing children at ages 4, 5 and 6 years, Walker and Archibald (2007) questioned the generally held belief that increasing rate simply reflects the maturity of the child's speech motor system. They reported that articulation rate did not increase significantly between 4 and 6 years. Although at 6 years of age the children presumably had more mature motor control than when they were 4 years of age, their rates were only a little faster. Furthermore, at 5 years of age the children produced slower rates than they did at 4 and 6 years of age. Walker and Archibald (2007) advised that speaking rate is a highly complex process, involving cognitive, linguistic and motor variables and proposed that factors other than motor maturation may account for their results. For example, the increasing phonological and syntactical demands placed on a child's developing motor system at age 5 years, may account for the slower rates produced by the children at this age.

In other studies, Walsh and Smith (2002) and Smith and Zelaznick (2004) used kinematic analyses to study jaw and lip movements of typically-developing participants, aged 4-22 years, when producing phrases. They found that consistency and speed of production increased with age as did synergy between different articulatory movements. However, they were not fully adult-like, even at 16 years of age. By 12 years of age, children were speaking at 90% adult speaking rates. However, the development of the final 10% adult speaking rate occurred late, between 16 and 21 years of age. Walsh and Smith (2002) concluded that there is a protracted developmental time course for speech motor processes that extends beyond age 16 years.

2.2.10 Atypical speech motor development 4 to 5 years and beyond

There is some research evidence that pre-school and school-aged children with speech difficulties have motor constraints. For example, Waters (1995) reported a study in which she used spectrographic analysis of connected speech data elicited by delayed imitation, to investigate the speech motor maturity of 12 children, aged 3.8-4.10 (mean 4;4), with developmental phonological disorders and compared their performance to 12 typically-developing controls aged 3;8 -4; 9 (mean 4;4). The results showed that as a group, the children with developmental phonological disorders spoke at significantly slower rates than the typically-developing controls, and exhibited longer phrase and segment durations, as well as demonstrating some differences in timing of voice onset. Waters (1995) concluded that poor speech motor control was likely to be a factor in accounting for the phonological difficulties of some children.

Flipsen (2002) investigated articulation rate in the conversational speech samples of two groups of children with speech delay, at two time points: at 3-6 years and then at either 9 years of age or at 12-16 years of age, depending on whether they were in the Early Follow- Up Group (n=17) or in the Late Follow Up Group (n=36). He compared their articulation rates to published normative data (including: Pindzola et al, 1989; Walker et al., 1992; Amster,1984; Haselager et al. ,1991; Hall et al., 1999). Both groups of children produced significantly faster rates at follow up than at initial testing. At both time points, the children with speech difficulties, as groups, produced similar rates to data reported in syllables per second for typically-developing children of similar ages. However, there was considerable individual variation and at least some clinical children were producing slower articulation rates in comparison to the data from typically-developing children of the same age at initial testing. These results have to be considered with some caution since the published studies involved different methodologies, including different tasks and different methods of data collection as well as different participants, from a number of different countries. Nevertheless, they do indicate that some individual children with speech difficulties are likely to speak at a slower rate than typically-developing children of the same age.

Studies have also reported evidence of speech motor constraints, other than rate, in school-age children with speech difficulties. For example, Gibbon (1999) reported a study of 17 children, aged 4 -12 years (mean age 8.5 years), with articulation and phonological difficulties of unknown aetiology, using Electropalatography (EPG) to provide visual feedback. She found that 12 of the 17 children (71%) demonstrated an unusually high level of tongue-palate contact visible on EPG frames, during production of lingual consonants, which she termed "undifferentiated lingual gestures" (ULGs). Gibbon (1999) interpreted these findings as reflecting a speech motor constraint that was occurring as a result of either delayed or deviant control of independent regions of the tongue (tongue tip/blade, tongue body and lateral margins). The remaining children (n=5) did not show evidence of having ULGs, although they did demonstrate some evidence of discrete difficulties with tongue tip/blade groove formation required to produce sibilant targets. Gibbon (1999) advised these children had less severe speech motor constraints than the children with wide-spread evidence of ULGs. Furthermore, she cites evidence from Howard (1998) based on EPG findings, that children with developmental speech difficulties generally demonstrate more difficulty with fine-tuning tongue tip/blade movements than they do in mastering tongue body movements.

Although the use of EPG has been very informative about the nature of school-age children's typical and atypical speech productions, this instrumental visual feedback technique is not appropriate for use with pre-school children. Thus it has been difficult to determine if ULGs occur in younger typically-developing children and are therefore indicators of speech motor delay or whether they do not occur in younger children and are therefore indicators of speech motor disorder. A different visual feedback instrumental technique using ultrasound has now been developed for use in speech intervention studies (Cleland, Scobie & Zharkova, 2016). Although most studies to date have included school age children and adolescents, recently there has been case study evidence of its use in attempting to remediate velar fronting with two pre-school children aged 4 years (Qi Wen Heng et al., 2016). The results showed improvement for one of the children in using /k/ and /g/ at syllable and word level, but the other child showed no improvement in using velar targets. Further studies are required, but it is possible that ultrasound may enable further investigation of tongue control during speech production with pre-school children.

A different aspect of speech motor control was investigated by Grigos et al. (2015). They studied movement of the jaw, lower and upper lip during a naming task with 33 children, aged 3-7 years. The children were subdivided into three groups: a group of typically-developing children (TD, n=11), a group of children with CAS (n=11) and a group of children with articulation and phonological speech difficulties (SD, n=11). They reported that both groups of children with speech difficulties (SD and CAS) showed more difficulties with temporal control than the TD children, but movement variability was significantly higher in the group with CAS than in the other two groups. All children were affected by word-length, but the children with CAS produced more movement duration and variability when they produced 3 syllable words, than the children in the other two groups (TD and SD).

2.2.11 Summary of typical and atypical speech motor development

In typical development, speech motor skills are acquired gradually with core development occurring 0-4 years, but further fine tuning continues into the mid-late teenage years. Children with speech difficulties struggle to move through the typical developmental phases and in severe cases may be 'arrested' at a particular phase. It is how they struggle or at which phase(s) they are 'arrested' that reveals the nature of their speech difficulties. Difficulties with DDK tasks may be associated with limited experience of canonical and variegated babbling, with the acquisition of individual segments, and/or with the development of stress, rhythm and fluency.

2.3 Assessment of Speech

Assessment is one of the key professional roles of SLTs/SLPs (RCSLT, 2006; ASHA, 2007). When a child presents with speech difficulties, the assessment procedure begins with a detailed case history and consideration of communication skills and overall development (Williams & Stephens, 2004). Areas investigated may include: play, social skills, attention, communication skills, verbal comprehension, expressive language, oral examination, phonology, articulation, voice, prosody, auditory skills, gross and fine motor skills, visual/tactile skills, non-verbal skills and emotional well-being (RCSLT, 1998). Other professionals, such as audiologists, paediatricians, occupational therapists, educational and/or clinical psychologists may also contribute to the assessment. This detailed approach to assessment ensures that a child's speech difficulties are considered in a holistic manner, within the context of their overall functioning and development.

Bowen (2015) advises that assessment of a child presenting with speech difficulties should begin with three core elements – an audiogram to assess peripheral hearing, an oral musculature examination to assess structure and function of the articulators, and a detailed case history. Case history information is typically collected from parents by carrying out a verbal interview or by asking parents to complete written questionnaires (e.g. Stackhouse et al., 2007). This provides background information about the child in terms of their development (both general and specifically speech and language), medical history, family background and history, education and any previous involvement with speech and language therapy services. It also provides the opportunity for parents to identify their concerns and express their desired outcome of the assessment procedure. Furthermore, case history information can indicate risk factors that are known to be associated with speech difficulties. For example, Fox, Dodd and Howard (2002) found that pre- and peri-natal problems, ear, nose and throat problems (ENT), sucking habits and family history of speech and language difficulties, distinguished a group of children with speech difficulties (n=65), aged 2; 7 - 7;2, from a group of typically-developing controls (n=48), aged 3;4 - 6;1. In addition, they also identified 'red flags' for speech impairment (Bowen 2009; 2015), such as unusual early vocal development, absent or late development of babble, late development of first words and word-joining and very limited consonant and vowel inventories. Following their longitudinal study, Stackhouse et al. (2007) also reported that late acquisition of first words was a significant case history factor which distinguished between a group of children with primary speech difficulties and a group of typically-developing controls matched on age, non-verbal IQ, and environmental factors such as schooling and mother's education. Other significant differentiating case history factors were being later born in a larger family, a higher occurrence of coughs and colds and a higher occurrence of visual difficulties in need of correction by wearing glasses.

The two other core elements essential to a speech assessment listed by Bowen (2015) concern functioning at the input and output peripheral levels of the speech processing profile (Stackhouse & Wells, 1997). Along with the box-and-arrow and phase models presented in Chapter One, Stackhouse and Wells (1997) have developed a speech processing profile as a tool for collating and interpreting such assessment results, along with exercises to establish 'what do tests really test' in order to check/establish what skills assessment tasks are really tapping. This profile is based on their theoretical box-and-arrow speech processing model and encourages a systematic assessment of a child's speech processing skills (see figure 2. 1.)

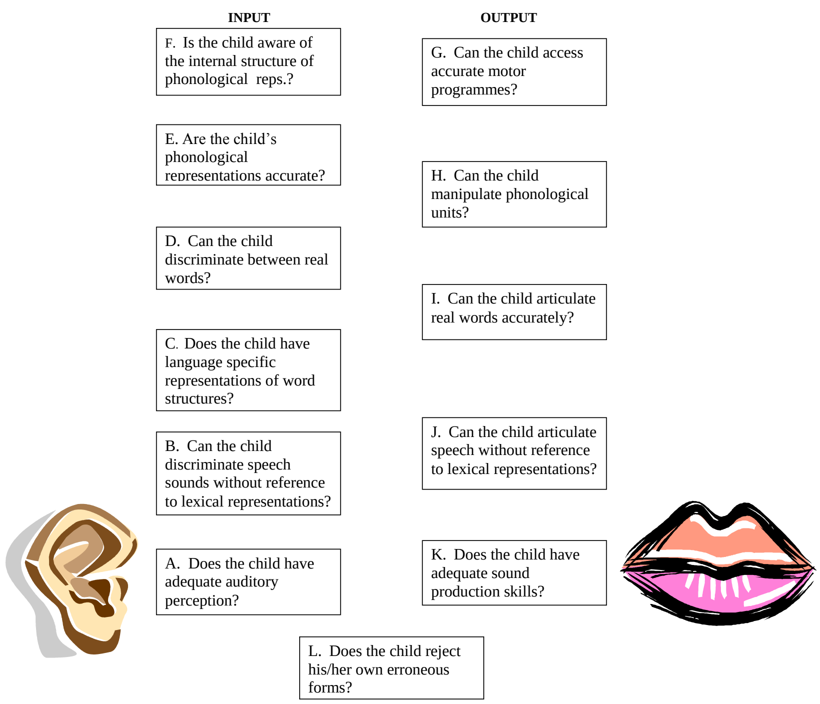


Figure 2.1 Speech Processing Profile (Stackhouse & Wells 1997).

The left hand side of the profile asks questions about a child's speech input processing, and the right hand side focuses on a child's output processing . Answering the questions higher up the processing profile involves investigating the child's stored representations. The questions lower down the profile address more peripheral skills. For example, on the lower left of the input side, an audiogram or other robust measure of hearing is required to answer the question at level A: *Does the child have adequate auditory perception?* At the equivalent point on the output side, an oral assessment of the articulators is required to answer the question at level K: *Does the child have adequate sound production skills?* and is essential to rule out any structural defects and to assess oro-motor functioning. Further investigations determine an individual's strengths and weaknesses at other input and output processing levels. In the following description, more detail will be provided of processing levels with examples of assessment tasks such as mispronunciation detection tasks (MDTs), real and non-word repetition tasks, and the Oro-motor, Phonology and Inconsistency assessments from the DEAP (Dodd et al., 2002).

2.3.1 Assessment of Input and Phonological Representations

There has been increasing acknowledgement that assessment of a child's speech difficulties should include tasks to assess input and representational processing levels, in addition to output processing (Stackhouse & Wells 1993; 1997; McLeod & McCormack 2007; Rvachew & Brosseau-Lapre, 2012). In the *Compendium of Auditory and Speech Tasks* (Stackhouse et al., 2007), a range of auditory tasks (beyond the level of peripheral hearing) are described which can be used to draw up a child's speech processing profile in terms of input and representational skills and to compare with their output skills. Auditory discrimination tasks involving non-words tap speech processing at level B: *Can the child discriminate speech sounds without reference to lexical representations?* In comparison, auditory discrimination tasks involving real words tap speech processing at level D: *Can the child discriminate between real words?* Auditory lexical or mispronunciation detection tasks (MDTs), which use pictures to investigate the accuracy of a child's phonological representations tap speech processing at level E: *Are the child's phonological representations accurate?*

2.3.1.1 Mispronunciation Detection Tasks (MDTs)

Children with speech difficulties may have under-specified phonological representations at least for some words or some parts of words, for example onset or coda position (Rvachew & Brosseau-Lapre, 2012), and this is likely to cause problems when they attempt to create motor programmes for spelling as well as for speech output (Stackhouse & Wells, 1997; Vance

Stackhouse & Wells, 2005). MDTs, also known as auditory lexical decision tasks (Locke, 1980b), are useful tools for assessing the accuracy of a child's phonological representations. They require the child to detect whether the tester's pronunciation of a picture name is produced correctly or not by making a comparison between what they perceive the tester says and their own stored representations of the word the picture denotes. It requires use of both semantic and phonological representations: semantic to access the name of the picture identified, and phonological to reflect on how the name of the picture is represented phonologically in their own store. The task involves both auditory discrimination and lexical decision since some of the tester's productions of the picture will result in a non-word (e.g. /fɪs/ for a picture of a fish).

MDTs are a particularly suitable tool for assessing the accuracy of phonological representations in children with speech difficulties, since they do not require a verbal response and unlike many tests can be used with pre-school children (Stackhouse et al, 2007). Typically, pictures are presented one by one to the child (by hand or on a computer) and the tester names the picture (using live or recorded voice), with either a correct or incorrect pronunciation. The child is required to indicate whether the spoken production was correct or incorrect by e.g. pointing/ using the computer mouse to select a symbol for yes or no, or nodding /shaking their head, or showing thumbs up or thumbs down. To do this successfully they need to compare what they have heard with their own stored representation of that word. A failure to recognise a mispronunciation of a target word indicates the child has not stored a clear phonological representation of that word since they accept similar sounding but wrong pronunciations as correct.

MDTs have been included in studies of typically-developing children (aged 3-7 years), children with speech difficulties, children with language difficulties and children identified as being at risk of having dyslexia. Table 2.1 lists these studies and provides a summary of the participants.

Table 2.1 Studies involving Mispronunciation Detection Tasks (MDTs): Authors, dates and participants.

Study: Authors and Date	Participants
Vance, Stackhouse & Wells (1995)	TD children (aged 3-7 years)
Carroll et al. (2003)	TD children (aged 4 years)
Carroll & Snowling (2004)	TD children; SD children; children AR dyslexia (aged 4-6 years)
van Alphen et al. (2004)	TD children; SLI children; children AR dyslexia (aged 5 years)
Sutherland & Gillon (2005) & (2007)	TD children; SD children (aged 3-5 years)
Nathan et al (2004); Stackhouse et al. (2007)	TD children; SD children (aged 4-7 years)
Vance, Rosen & Coleman (2009) SIPc	TD children (aged 4-5 years)
McNeill & Hesketh (2009)	TD children (aged 4-5 years)
Claessen et al. (2009)	TD children (aged 5-7 years)

Key: TD =typically-developing children; SD = children with speech difficulties; SLI = children with specific language impairment; AR =at risk of.

In summary, findings from the studies in table 2.1 have shown:

- Performance of typically-developing children improves with age and with exposure to literacy acquisition (e.g. Vance et al. 1995; Carroll et al., 2003; Claessen et al., 2009; McNeill & Hesketh, 2009; Vance et al. 2009). As a child's phonological representations become more distinct and segmental (i.e. organised at the phoneme level), it is easier for them to detect minimal sound changes, such as a single feature change in a phoneme (Elbro, 1996; Metsala & Walley 1998).

- Typically-developing children perform better on MDTs than children with speech difficulties, children with language difficulties, and those at risk of dyslexia (e.g. Caroll & Snowling, 2003; van Alphen et al., 2004; Sutherland & Gillon, 2005; Sutherland & Gillon, 2007; Stackhouse et al., 2007).

- Maximal or "coarse-grained" mispronunciations, e.g. transpositions of consonant sounds or consonant changes involving more than one phonetic feature, are easier for children to detect than minimal or "fine-grained" mispronunciations e.g. consonant changes involving a single phonetic feature (e.g. van Alphen et al., 2004; McNeill & Hesketh, 2009).

- Mispronunciations involving vowel changes are difficult for children to detect (McNeill & Hesketh, 2009; Claessen et al., 2009).

- Children find it harder to detect a mispronounced version than a correct version of a target item (e.g. Sutherland & Gillon, 2005; Claessen et al., 2009).

- The presentation of MDTs should ideally match the child's own accent or at least be dialect specific (Rvachew & Brosseau-Lapre, 2012), e.g. for English speakers: American English, Australian English, New Zealand English, English spoken in England, UK.

2.3.2 Assessment of Speech Output

McLeod and McCormack (2007) advise that an assessment of speech output should include:

- Speech sounds the child can produce (phonetic ability)
- Accuracy of speech sounds with respect to the language they are speaking (phonological ability).
- The child's ability to combine sounds (phonotactic ability).
- The child's ability to produce appropriate intonation, stress and rhythm (prosodic ability).

There is no official guidance regarding the tools that should be employed by SLPs/SLTs in carrying out a speech output assessment and there is an array of available published assessments; for example, Bowen (2009) lists eighteen commonly cited child speech assessments, and Joffe and Pring (2008) reported that UK SLTs used twenty-one different assessments. Recent UK Good practice guidelines for transcription of children's speech samples in clinical practice and research[6] (UK and Ireland Specialists in Specific Speech Impairment (SSSI) Network, 2013) have proposed that a preliminary speech assessment sample should consist of: (a) a screening list of around sixty single words, derived by picture naming (not imitation) and (b) a small amount of connected speech.

The single words used in the picture naming task should include as many consonants in as many syllable/word positions as possible, a range of long, short and diphthong vowels (as appropriate for the child's accent) and some polysyllabic words. Polysyllabic words contain more syllables, a greater range of consonant sequences and a wider range of stress variations, than shorter word structures. Studies have shown that typically-developing children are less accurate in producing polysyllabic words than bi-syllabic and mono-syllabic words (Ingram et al., 1980; Vance et al., 2005; James, 2006; James, Van Doorn & McLeod, 2008). Children with speech difficulties often have similar but more significant difficulties with polysyllabic words than TD children. In particular, checklists of diagnostic features of DVD often include: increased difficulty with longer and more complex words (e.g. Stackhouse, 1992; Davis, Jakielski &

[6] Abbreviated to Good practice guidelines from here on.

Marquardt, 1998; McCabe, Rosenthal & McLeod, 1998; Ozanne, 1995; 2005; Shriberg, Potter & Strand, 2011; RCSLT, 2011). Murray et al. (2015) assessed forty-seven children, aged 4-7 years, with suspected CAS on a multisyllabic picture naming task: the Single-Word Test of Polysyllables (Gozzard, Baker & McCabe, 2004; 2006) and on the DEAP Inconsistency Assessment (Dodd et al., 2002). In order to determine if the children had more difficulty producing longer and more complex words than they did producing shorter and less complex words, Murray et al. (2015) compared the children's responses on the first twelve items of the polysyllabic naming test to their responses on the first twelve mono-syllabic items on the DEAP Inconsistency Assessment (Dodd et al., 2002). Although it could be argued that these assessment items were not phonetically matched, it is one of the few studies which specified how the feature of having more difficulty with longer and more complex words was determined. Murray et al. (2015) reported that this measure was non-significant in differentiating between children who the authors diagnosed as having CAS (n=32) and a non-CAS group (n=15), which included children with phonological disorder, dysarthria and submucous cleft. However, percentage phonemes correct (PPC) on the polysyllabic naming task did differentiate between the two groups.

James (2015) advised that some polysyllabic words are easier for children to say than others and she listed the following ten polysyllabic words as being the most clinically useful: AMBULANCE, HIPPOPOTAMUS, COMPUTER, SPAGHETTI, VEGETABLES, HELICOPTER, ANIMALS, CARAVAN, CATERPILLAR and BUTTERFLY. This was based on her study of typically-developing children (n=283), aged 3;0 - 7;11 (James, 2006) which found age-differences on these particular polysyllabic words. These words all share features, such as: (a) they include non-final weak syllables with sonorant onsets and codas, (b) they include consonant sequences, particularly involving an anterior/posterior movement, and (c) they include consonants (especially sonorants) that share place or manner features.

Whilst recognising the importance of including polysyllabic words in a speech assessment, for children with severe motor speech difficulties, this may be too daunting a task for some. Such children need an assessment procedure which puts the focus on earlier developing consonant sounds, paired with a range of vowels and diphthongs, in simple syllable structures, i.e. CV, VC, CVCV, CVC. For example, the *Nuffield Dyspraxia Programme Assessment* (NDPA) (Williams & Stephens, 2004) and the *Dynamic Evaluation of Motor Speech Skill* (DEMSS) (Stand et al., 2013) both aim to do this.

The Good practice guidelines (UK and Ireland SSSI Network, 2013) also advise that the word screening list should have the potential to assess variability of speech production by assessing each consonant in each word position, in a range of contexts and on more than one occasion. No specific assessment tool is recommended, but it is recognised that many available published speech assessments would meet these criteria. The connected speech sample should be on a known topic so that intelligibility can be rated and segmental and supra-segmental (prosodic) features can be assessed. Again, no specific assessment tool is advised but suitable tasks could include descriptions of action pictures or sentence repetition (see Chapter 6 in Stackhouse et al., 2007 for further discussion).

The aim of this preliminary assessment is to identify if the child requires intervention and if so, what the priority targets would be. These might include a single sound, a class of sounds, a phonological process or a sound in a specific word position. At this stage, it is advised that stimulability of target sounds is assessed in isolation and in non-words in order to determine whether or not the child can articulate the sound(s). A probe list of additional single words in the target areas should also be administered, so that sounds can be assessed in different phonetic contexts and in words involving different numbers of syllables.

In addition to this single word sample, the Good practice guidelines (UK and Ireland SSSI Network, 2013) suggest that a larger connected speech sample is collected, through conversation interchanges, sentence repetition, picture descriptions and/or narrative productions. In the literature, recommendations regarding the length of a connected speech sample are highly variable, with no consensus agreement. For example, Shriberg & Kwiatkowski (1982) suggested a conversation sample of two hundred words should be collected, whereas Bauman-Waengler (2011) suggested collecting three minutes of conversational speech. Dodd et al. (2002) use three pictures at the end of the Phonology subtest to elicit connected productions and to allow comparisons of the production of fourteen key words in single words and in connected speech. In comparison, Klinto et al. (2011) used thirteen repeated sentences to compare single word and connected speech accuracy.

The connected speech sample allows the clinician to consider how consonants and vowels are used in joined productions, as distinct to their use in single words, and how sounds and syllables are joined at word boundaries. Furthermore, it forms the basis for intelligibility ratings and allows assessment of supra-segmental features such as voice, resonance and prosody. Speaking rate is one particular aspect of prosody which can be measured from a connected speech sample. Adult speakers of English are reported to speak at a rate of 5-6 syllables per second, depending on the variety of English being spoken (Robb & Gillon, 2007). In comparison, children have been found to speak at a much slower rate than adults, depending on age and speaking context (e.g. spontaneous speech, imitated speech and automatic speech, such as reciting a nursery rhyme). In their longitudinal study of sixteen children at ages 4, 5 and 6 years, Walker and Archibald (2006) reported that articulation rates (with pauses removed) averaged across four different contexts were : 3.749 syll/sec. at 4 years; 3.389 syll/sec. at 5 years, and 3.762 syll/sec. at 6 years. Thus, there was no developmental progression in speaking rate between 4 and 6 years of age. Other studies have mainly reported rates only for spontaneous speech, using different methods of measurement, and have included children of varying ages e.g. Amster (1984) reported articulation rates of 3.06 syll/sec. for American English speaking 4 year old children and 3.34 syll/sec. for 5 year old children; Haselager et al. (1991) reported articulation rates of: 4.01 syll/sec. for Dutch speaking children aged 5 years and 4.51 syll/sec. for children aged 7 years.

2.3.2.1 Standardized Speech Assessments (UK)

Only two standardized paediatric speech assessments have been published in the UK. The first was published in 1971: *The Edinburgh Articulation Test* (EAT) (Anthony et al., 1971), a single word picture naming test, which was standardized on 510 Scottish children aged 3;0-6;0 years. It samples a child's articulatory abilities in terms of singleton consonants and consonant clusters and allows for both quantitative and qualitative analysis of errors. It has been out of print for many years, but copies still exist in speech and language therapy clinics and it is still sometimes used when age equivalent measures are required.

The only current standardized speech assessment used in the UK is the *Diagnostic Evaluation of Articulation and Phonology* (DEAP) (Dodd et al., 2002). Given its status, it may seem surprising that it was not named in the survey of clinical practice for children with phonological problems carried out by Joffe and Pring (2008). However, the survey was conducted between 2002 and 2003, just as the DEAP was published in the UK and this is likely to account for its absence. The DEAP (Dodd et al., 2002) is designed to provide a differential diagnosis of speech disorders for children aged 3;0-6;11 in terms of: articulation disorders, delayed phonological development, consistent and inconsistent phonological disorder. It comprises five subtests:

(a) The Diagnostic Screen, takes five minutes to administer, and requires the child to name ten single word pictures twice, separated by a single sound imitation task for any sounds produced in error. This allows identification of a speech difficulty and which aspects need further assessment, using one or more of the following four subtests.

(b) The Articulation Assessment determines whether a child can produce a perceptually acceptable speech sound. It should be administered if the sample produced in the diagnostic screen indicates phonetic errors and/or if the child is unable to imitate age-appropriate sounds in isolation. The test is administered as a two-step procedure: firstly, the child is asked to name thirty pictures of single words, which have mainly a CVC syllable structure. Virtually all vowels and all consonants, in syllable initial and syllable final position, are sampled. If the child fails to produce a sound correctly on the picture naming task, he/she is allowed three attempts to imitate the sound in a syllable (examples are provided on the record sheet). If this is unsuccessful, the examiner asks the child to imitate the sound in isolation. No age norms are provided for the picture naming task, but age of acquisition norms (i.e. when acquired by 50%, 75% and 90% of children in the normative sample) for single consonants are given.

(c) The Oro-motor Assessment screens a child's oro-motor function and should be administered either in conjunction with the Articulation Assessment when there is evidence of phonetic difficulties, or with the Inconsistency Assessment when there is significant evidence of Inconsistency (>50% on the Diagnostic screen). This assessment requires the child to imitate four isolated volitional movements (I-M) and three sequenced volitional movements (S-M) (the tasks are adapted from Ozanne, 1992). In addition, a DDK task is included in which the child is asked to repeat the polysyllabic word PAT-A-CAKE five or ten times (depending on age) and performance is rated in terms of sequencing, intelligibility and fluency measures. Standard scores and percentiles are provided for each of the three tasks (I-M, S-M, DDK) in six month age groups.

(d) The Inconsistency Assessment should be administered if the child produces >50% productions differently when naming the ten single words on the diagnostic screen on two occasions. This assessment allows the clinician to evaluate the stability of the child's phonological system by requiring the child to name a set of twenty-five pictures on three occasions within the same session, with each trial separated by another activity. For each item, the child scores 0 if all three productions are the same, or 1, if any of the three productions differ. These scores are added together and an Inconsistency score is calculated. Dodd et al. (2002) advise that if this results in a score of 40% or more, the clinician should re-examine the data and check whether any of the differences across the three trials are variations between a correct production and a developmentally age appropriate response. If they are, these variations should be removed and the inconsistency score re-calculated. A final score of 40% or more indicates inconsistent speech production. Administration of the Oro-motor assessment is advised to differentiate between children who have Inconsistent Phonological Disorder (IPD) and those with Developmental Verbal Dyspraxia (DVD) (RCSLT, 2011). According to Dodd et al. (2002), children with DVD would be expected to demonstrate oro-motor difficulties, whereas children with IPD would not.

(e) The Phonology Assessment should be administered if the child can imitate speech sounds in isolation or in CV/VC syllables, but is making error patterns which are not age appropriate. It aims to determine the use of surface error patterns (phonological simplification processes) within the child's speech e.g. fronting, stopping, gliding, cluster reduction. The child is asked to name fifty single word pictures, which sample all vowels and diphthongs and all consonants in syllable initial and syllable final position, as well as bi- and tri-cluster combinations. In addition, the child is asked to describe three 'funny pictures', which aim to elicit fourteen items from the single word naming task in a connected utterance. This enables a small sample of connected speech to be collected, which can be examined for prosodic features and also allows a comparison to be made between a child's production of single words, with their production of those words in connected utterances. Standard scores and percentiles are provided for Percentage Consonants Correct (PCC), Percentage Vowels Correct (PVC), Percentage Phonemes Correct (PPC) and Single words vs. Connected speech agreement (SvsC) in six month age bands. In addition, ages when individual phonological error patterns were typically surpressed in the normative sample are given.

2.3.2.2 Analyses of Assessment Data

Two types of analysis are commonly reported in the literature:

(a) An independent analysis which provides a view of the child's unique profile without reference to the adult target. This should include: a consonant inventory, a vowel inventory, a phonotactic or syllable-word shapes inventory (e.g. CV, VC, CVCV, CCV etc.) and an inventory of syllable stress patterns. By building these inventory lists from the obtained speech sample, constraints operating in different aspects of the child's speech can be identified. These might include absent phonemes, phonemes restricted in use to only certain positions within words, a reduced range of syllable-word shapes and a limited range of syllable stress patterns.

(b) A relational analysis provides a comparison between the child's current performance and the adult target. It includes measures such as Percentage of Whole Words Correct (PWC), Percentage Consonants Correct (PCC), Percentage Vowels Correct (PVC), Percentage

Phonemes Correct (PPC), Proportion of Whole Word Proximity (PWP), Percentage occurrence of phonological simplification processes/ phonological error patterns, Substitution, Omission, Distortion, Addition (SODA) analysis and Place-Voice-Manner (PVM) analysis. Provided that a sample of connected speech has been collected as well as single word data, it is also possible to make a comparison between scores obtained on the above measures in single words and in connected speech.

Although many of the above analyses are in common use, some have been identified as being more useful than others in tracking children's speech production changes over time. For example, Newbold, Stackhouse and Wells (2013) used PWC, PCC, PWP, phonological process analysis and phonetic inventory analysis to examine single word naming and repetition data produced by four children with severe speech difficulties at 4 and 6 years of age. They found PWC was not sensitive enough to show speech changes over time, but PCC and PWP were and are therefore recommended for measuring intervention outcomes.

2.3.2.3 Real and Non-word Repetition Tasks

Within their Psycholinguistic Assessment Framework, Stackhouse & Wells (1997), propose that it is necessary to compare a child's performance on different output tasks such as picture naming, real word (RW) repetition and non-word (NW) repetition, in order to identify a profile of individual speech processing strengths and weaknesses. They chart the different routes these tasks take through a theoretical speech processing model in order to aid interpretation of a child's task performance. This performance can be recorded on the speech processing profile. Picture naming tasks tap speech processing at level G on the Speech Processing Profile in Figure 2.1 to answer the question: *Can the child access accurate motor programs?*, whereas RW repetition taps processing at level I, to answer the question: *Can the child articulate real words accurately?*; NW repetition taps processing at level J and answers the question: *Can the child articulate speech without reference to lexical representations?*

RW and NW repetition tasks have been included in studies of typically-developing children (aged 2-7 years), children with speech difficulties, children with language difficulties and children with literacy difficulties. Table 2.2 lists these studies and provides a summary of the participants.

Table 2.2 Studies involving RW and NW repetition tasks: Authors, dates and participants.

Study: Authors and Date	**Participants**
Dollagahan et al. (1995)	TD and LD children (school aged)
Bishop, North & Donlan (1996)	TD and LD children (school aged)
Leitao et al. (1997)	TD, SD and LD children (aged 6 years)
Dollaghan & Campbell (1998)	TD and LD children (aged 6-9 years)
Roy & Chiat (2004)	TD children (aged 2-7 years)
Nathan et al. (2004)	TD and SD children (longitudinal study, aged 4-7 years)
Lewis et al. (2004)	TD, SD and LD children (longitudinal study, aged 4-6 years & 8-10 years)
Vance et al. (2005)	TD children (aged 3-7 years)
Munson et al. (2005)	TD and SD children (aged 3-6 years)
Catts et al. (2005)	Lit.D children
Archibald & Gathercole (2006)	TD and LD children (aged 7-11 years)
Chiat & Roy (2007)	TD and LD children (aged 2-4 years)
Preston & Edwards (2007)	TD and SD children (aged 10-14 years)
Bishop et al. (2009)	LD and Lit.D children (aged 9-10 years)
Shriberg et al. (2009)	TD and SD children (aged 3-5 years
Shriberg et al. (2012)	TD, SD and LD children (aged 3-6 years & 7 years+)
Rispens & Baker (2012)	TD, LD and Lit. Children (aged 5-8 years)

Key: TD =typically-developing children; SD = children with speech difficulties; LD = children with language difficulties; Lit.D = children with literacy difficulties.

Findings from these studies have shown:

- Typically-developing children as young as 2;0 years of age can carry out RW and NW repetition tasks (Roy & Chiat, 2004).

- Typically-developing children aged 2-7 years repeat RWs more accurately than NWs (Roy & Chiat, 2004; Vance et al., 2005; Chiat & Roy, 2007).

- Typically-developing children aged 2-7 years repeat shorter RW and NW targets more accurately than longer targets (Roy & Chiat, 2004; Vance et al., 2005; Chiat & Roy, 2007).

- Typically-developing children, aged 2-7 years, rarely omit stressed syllables in RW and NW repetition tasks; however, they may omit unstressed syllables in pre-stress position (i.e. before the primary stressed syllable) (Chiat and Roy, 2007).

- Typically-developing children's accuracy on both RW and NW repetition tasks improves with age between 3 and 5 years (Vance et al., 2005).

- Children with language impairment perform more poorly than typically-developing children on NW repetition tasks (Bishop, North & Donlan, 1996; Dollaghan & Campbell, 1998; Archibald & Gathercole, 2006).

- Children with literacy difficulties perform more poorly than typically-developing children on NW repetition tasks (Catts et al., 2005; Bishop et al., 2009; Rispens & Baker, 2012).

- Children with speech difficulties perform more poorly than typically-developing children on RW repetition tasks (Leitao, 1997; Lewis et al, 2004).

- Children with speech difficulties find NW repetition tasks challenging and score more poorly than typically-developing children (Nathan et al., 2004; Munson et al., 2005).

- Children with speech difficulties find it easier to repeat NWs which most closely resemble RWs (Dollaghan et al., 1995; Dollaghan & Campbell, 1998; Roy & Chiat, 2004; Munson et al., 2005; Archibald & Gathercole, 2006; Chiat & Roy, 2007).

- NW repetition performance in children with speech difficulties, in a longitudinal study of children aged 4-7 years, was predictive of both persisting speech and literacy difficulties (Nathan et al, 2004; Stackhouse et al., 2007).

Tests have been developed to assess the NW repetition skills of children with language impairment, such as *The Children's Nonword Repetition Test* (CNRep) (Gathercole and Baddeley, 1996) and *The Nonword Repetition Test* (NRT) (Dollaghan & Campbell, 1998). Shriberg et al. (2009) were aware that scoring difficulties arose on these tests when testing children who had both speech and language impairments. Therefore, they developed *The Syllable Repetition Test* (SRT) for use in speech-genetics research, to try and limit the impact that speech production errors have on an individual's performance on NW repetition tasks. The SRT consists of fourteen items: eight bi-syllables (CVCV); six tri-syllables (CVCVCV) and four quadruple syllables (CVCVCVCV). There is only one vowel throughout (/a/) and four different early-developing consonants (/b, d, m, n/). The vowel is not scored but each correct consonant scores two points. Each syllable on the SRT is modelled with equal stress. Shriberg et al. (2009) explained that the absence of prosodic stress enabled the scoring system to be as simple as possible and furthermore, equal syllabic stress has the advantage of maximising auditory information. It was presumed that children are likely to perceive these syllable strings as potential words, even without the presence of stress cues.

In order to assess the validity of the SRT, Shriberg et al. (2009) compared the performance of two groups of pre-school mono-lingual children (n=95 with speech delay and n=63 typically-developing) on the NRT (Dollaghan & Campbell, 1998) and the SRT. The results were as follows:-

a) when the authors examined conversation samples (from 99 children across the two groups of children), they found that all the four consonants and one vowel /b, d, m, n, a/ from the SRT were present in their phonetic inventories, whereas six of the twenty phonemes from the NRT were not present in at least some of the children's phonetic inventories.

b) the SRT was successful in identifying expressive language impairment in the children, with 68% accuracy, which was at a similar level to the NRT. Performance on the SRT provided interim support for an auditory-perceptual encoding constraint, in addition to memory constraints (affecting storage and retrieval of representations), which contributes to NW repetition errors in children with speech delay and expressive language impairments.

Shriberg et al. (2012) also used the SRT to investigate the speech processing deficits of a group of 40 children with CAS compared to three other groups: a) children with typical speech & language (n=119); b) children with speech delay, but typical language (n=140); and c) speech delay and language impairment (n=70). To be included in the CAS group, they had to demonstrate 4 of 10 perceptual features on three different assessment tasks (Shriberg, Potter & Strand, 2011). The group with CAS scored significantly lower on the SRT and on other encoding, memory and transcoding measures in comparison to the controls. Shriberg et al. (2012) concluded that as a tool, the SRT has moderate diagnostic accuracy in identifying planning and programming deficits in CAS. Furthermore, the findings indicate that children with CAS do not only have transcoding (planning and programming deficits) as had previously been thought (ASHA, 2007), but they also have speech processing deficits in auditory-perceptual encoding and memory. This appears to support previous proposals that CAS/DVD is a multi-faceted condition, arising from a combination of deficits across the speech processing chain (Stackhouse, 1992; Ozanne, 1995).

2.3.2.6 Assessment of Single Sounds

Typically in a speech assessment, a child is asked to imitate single consonant and vowel sounds in isolation to establish a phonetic inventory of the sounds they can articulate. Dodd et al. (2003) established the *c*onsonant and vowel inventories for each child, in their study of 684 children aged 3;0-6;11. A phoneme was included in a child's phonetic inventory if it was produced spontaneously or in imitation (imitated sounds were accepted as evidence of articulatory competence). Non-dialectal phonetic variation (e.g. a lisp) was counted as an error. Individual results were collated together to produce normative data for children aged 3;0 to 6;11 divided into 6 month age bands (based on a criterion of sounds which could be produced by 50%, 75% and 90% of the children in a particular age group).

Dodd et al. (2003) do not report in detail on age of acquisition for vowels, although they note that almost all children produced almost all vowels correctly by 4 years of age. In the section about the Articulation Assessment in the DEAP manual, Dodd et al. (2002) advise that any child who is unable to imitate vowel sounds (to conform to their local variety of English) should be considered to have an articulation difficulty.

With regards to consonant sounds, typically /m,n,p,b,d,w/ are the first consonants children acquire and /r,θ,ð/ are the last consonants they acquire. Between the ages of 3;0 and 3;5 years, 90% of children have already acquired the majority of consonant sounds, across the sound classes (see Table 2.3).

Table 2.3 Phonetic acquisition –consonant sounds present in 90% of children aged 3;00-3;05 years.

Plosive	p b t d k g
Nasal	m n ŋ
Fricative	f v s z h
Approximant	w l j

By age 4;05, 90% of children have acquired the fricative /ʒ/ and the affricates /tʃ/ and /dʒ/. Once
/ʃ/ is acquired by around 5;05, it only leaves the approximant / r/ which is acquired by 6;05 and then the remaining fricatives /θ/ and /ð/ are acquired around 7 years and above.

On Stackhouse and Wells' (1997) Speech Processing Profile in Figure 2.1, assessment of single sounds contributes to answering the question at level K: *Does the child have adequate sound production skills?* Assessment of Oro-motor skills is also addressed at level K.

2.3.2.7 Assessment of Oro-motor Skills

An evaluation of oro-motor structure and function is considered to be a core element when assessing a child with speech difficulties (Ozanne, 1992; Bradford & Dodd, 1996; Bowen, 2009). As a minimum, a structural examination should be able to rule out any overt oro-facial abnormality, such as cleft lip and palate and a functional assessment should highlight any significant movement difficulties, associated with the innervation of the muscles in the vocal tract, such as in dysarthria. The need for such an assessment to be included in policy guidelines and clinical pathways was highlighted by Murray et al. (2015), following their attempt to recruit participants with CAS for an intervention study. Community based SLPs were invited to propose children aged between 4-12 years who they suspected of having CAS and who met the required inclusion criteria for the study. Murray et al. (2015) identified that a subset of the children referred to them had overt structural or neurological deficits which had not been identified by the community practitioners, including children as old as 12 years. By utilising the OMA (Robbins and Klee, 1987), which assesses structure and function, Murray et al. (2015) reported that the three children with sub-mucous clefts had low structure scores due to poor palatal junction and one also had a bifid uvula. The children with dysarthria scored not only poorly on the function assessment but also on the structure assessment because of tongue fasciculation, tongue atrophy and lack of tongue symmetry.

In addition to the OMA (Robbins & Klee, 1987), a number of other tests have been published which include assessments of children's non-verbal oral and speech motor skills. McCauley and Strand (2008) reviewed six standardized tests for validity and reliability and concluded that only the *Verbal Motor Production Assessment for Children* - VMPAC (Hayden & Square, 1999) provided evidence of validity and none of the tests provided adequate evidence of reliability.

2.3.2.8 Assessment of DDK Skills

DDK tasks are often included in Oro-motor assessments, for example, as in the OMA (Robbins & Klee, 1987), the VMPAC (Hayden & Square, 1999) and the DEAP Oro-motor Assessment (Dodd et al., 2002). In chapter one, findings on DDK performance by children with and without speech difficulties were described. In the following section, DDK task design, measurements and procedures will be reviewed.

Crary (1993) proposed that at least two basic questions need to be asked when selecting DDK tasks: (1) Which spoken targets /stimuli will be chosen? and (2) How will the child's responses be measured? Table 2.4 summarises the stimuli and measurements that have been adopted in published studies and procedures involving typically-developing children only and table 2.5 summarises the stimuli and measurements that have been adopted in published studies which have included children with speech difficulties.

Table 2.4 DDK Stimuli and Measurements used in published DDK Studies and Procedures involving typically-developing children.

Authors & Participants	DDK Stimuli	DDK Measurements
Fletcher (1972; 1978) USA. TD children, 6-13 years, in 8 age groups.	5 Mono-syllables repeated x 20 3 Bi-syllables repeated x 15 1 Tri-syllable [pʌtəkə] x 10	DDK rate using time-by-count method. Stop watch & oscillographic trace.
Canning & Rose (1974) UK. TD children 4;6-9;6 in 6 age groups & 13;6-14;6.	6 monosyllables repeated x 10 1 tri-syllable [pətəkə] or BUTTERCUP x 10	DDK rate using time-by-count method. Stop watch used.
Oliver et al. (1985) UK. TD children 8 -16 years in 8 age groups.	2 bi-syllables repeated x 10	DDK rate using time-by-count method. Stop watch used.
Robbins & Klee (1987) USA. TD children 2;6-6;11 in 9 age groups.	3 monosyllables repeated in 3 secs; 1 RW tri-syllable: PATTICAKE; 1 NW tri-syllable: [pərəkə]	DDK rate reported as number of repetitions per second. Stop watch used. Accuracy also scored.
St Louis & Ruscello (1987) USA. TD participants 5-77 years in 12 age groups.	3 monosyllables repeated x 16 1 bi-syllable repeated x 12 1 tri-syllable [pʌtəkə] repeated x 8	DDK rate using time-by-count method. Stop watch used. Accuracy also scored.
VMPAC Hayden & Square (1999) USA. TD children 3-6 & 7-12 years.	6 monosyllables repeated x 4 3 bi-syllables repeated x 4 2 tri-syllables repeated x 4	Accuracy Consistency
DEAP Dodd et al. (2002) UK. TD children 3;0-6;11 in 8 age groups.	1 tri-syllable PAT-A-CAKE repeated x 5 or x 10 depending on age.	Correct sound sequence Fluency Intelligibility
Williams & Stackhouse (2000) UK. TD children 3-5 years in 3 age groups.	10 bi-syllables repeated x 5 6 tri-syllables repeated x 5	Accuracy Consistency Rate: time-by-count method using stop watch.
Yaruss & Logan (2002) USA. TD children 3-7 years, in 5 age groups.	1 tri-syllable, either 'puh-tuh-kuh' or PATTICAKE repeated x 10	Accuracy Fluency Rate –measured objectively.

Key: TD=Typically-developing.

Table 2.5 DDK Stimuli and Measurements used in published DDK Studies and Procedures including children with speech difficulties.

Authors & Participants	**DDK Stimuli**	**DDK Measurements**
Yoss & Darley (1974) USA. TD & SD children 5-10 years.	3 monosyllables; 1 tri-syllable [pʌtəkə]	Rate –syllables per second. Observed consonant sequencing errors
McNutt (1977) USA. TD & SD adolescents 13-14 years.	1 bi-syllable: [dʌgə], as fast and for as long as possible.	Rate
Henry (1990) UK. TD & SD children 3-5 years.	3 monosyllables repeated x 10 6 bi-syllables repeated x 10 5 tri-syllables repeated x 10	Rate, using a stop watch Observed consonant sequencing errors
Bradford & Dodd (1996) Australia. TD & SD children 3; 2 -6;7.	Utilised OMA (Robbins & Klee, 1987): 3 monosyllables; 1 RW tri-syllable; 1 NW tri-syllable	Accuracy Rate
Thoonen et al. (1996; 1999) Netherlands. TD & SD children; 6-10 years (1996); 4-12 years (1999).	3 monosyllables 1 tri-syllable [pɑtaka]	Accuracy Rate, measured objectively in syllables per second.
Cohen, Waters & Hewlett (1998) UK. TD & SD children 3-5 years.	3 monosyllables 1 bi-syllable: [pətə] 1 tri-syllable [pətəkə] As many repetitions as possible	Rate –objective measurement in syllables per second. Only accurate productions included.
Dodd & McIntosh (2008) Australia. TD & SD children 3;1-5;6.	Utilised DEAP DDK task: 1 tri-syllable PAT-A-CAKE repeated x 5 or x 10 depending on age	Correct sound sequence Fluency Intelligibility
Preston & Edwards (2009) USA. TD & SD children 10-14 years.	1 tri-syllable: [pʌtʌkʌ] repeated 10 x	Accuracy Consistency Rate, measured objectively in seconds
Preston & Koenig (2011) USA. SD children 9;2-15;5.	1 tri-syllable: [pʌtʌkʌ] repeated 10 x in four consecutive trials	Consistency-number of different forms in 40 repetitions
Wren et al. (2012) UK. SD children 8 years.	2 tri-syllables: [pətəkə] & [bədəgə], repeated rapidly over at least a 10 second period.	Accuracy
Murray et al. (2015) Australia. SD children 4-12 years.	Utilised OMA (Robbins & Klee, 1987): 3 monosyllables repeated in 3 secs; 1 RW tri-syllable: PATTICAKE; 1 NW tri-syllable: [pərəkə]	Accuracy Rate

Key: TD children =Typically-developing children; SD children= Children with Speech Difficulties.

2.3.2.8.i DDK Stimuli

DDK assessments of children with and without speech difficulties have included mono-syllable, bi-syllable and tri-syllable targets. Kent et al. (1987) reported that the most commonly selected syllables in DDK tasks are the monosyllables /pə/, /tə/, /kə/ or their equivalent voiced counterparts /bə/, /də/, /gə/ and the most commonly selected tri-syllable is /pətəkə /. Yaruss and Logan (2002) advised that it may only be necessary to assess performance on tri-syllable targets since previous studies have indicated strong correlations between DDK rates based on mono-syllabic, bi-syllabic and tri-syllabic targets (Hale et al., 1992; Wolk et al., 1993).

Nonsense targets are usually preferred, as the primary purpose of DDK tasks is to measure neuro-motor rather than linguistic skill (Tiffany, 1980; Wilcox et al., 1996). However, some authors have reported that target tri-syllables such as /pətəkə/ are too abstract for young children (e.g. Canning and Rose, 1974) and have favoured using polysyllabic words such as BUTTERCUP or PAT-A-CAKE instead. However, as discussed above, children may perform differently on tasks comprising RW vs. NW targets since they tap different skills and routes through the speech processing model (Williams & Stackhouse, 2000; Vance et al., 1995). Tri-syllables such as /pətəkə/ are also simpler in structure than many English words since only syllable onset consonants are used and there is no vowel change throughout. Further these stimuli constitute illegal non-words in English since they comprise three equally stressed syllables resulting in them being even more likely to be treated differently from real words. Williams and Stackhouse (2000) utilised such psycholinguistic and phonetic principles to explain why it is important to distinguish between RW, legal and illegal NW DDK targets. In a study of TD children, aged 3-5 years, they compared the children's performance on matched RW, NW and syllable sequences (SS). Bi-syllabic and tri-syllabic NWs were derived from RW targets by maintaining the consonants, but changing the vowels. Vowel length was maintained, so alternative short vowels were substituted for short vowels and alternative long vowels/diphthongs were substituted for long vowels/diphthongs, e.g. DIGGER became /ˈdagɪ/ and PATACAKE became /ˈpɒtəkəʊk/. Illegal NWs, which were termed SSs, were derived from the RW and legal NW targets by maintaining the consonants but substituting a schwa vowel /ə/ for each vowel, e.g. DIGGER became [ˈdəˈgə] and PATACAKE became [ˈpəˈtəˈkə]. They were modelled as three equally stressed syllables. See Appendix 2.1 for further information about 1-3 syllable targets used in DDK assessments of TD children and those with speech difficulties.

2.3.2.8.ii DDK Measurement: Rate

Articulatory speed or rate has been the standard measure of DDK performance (Preston & Edwards, 2009). However, measuring DDK rate is not straightforward, and a range of different rates have been published in normative studies.

Cohen, Waters and Hewlett (1998) summarised five widely-used published procedures for the collection and analysis of DDK data from young children. The studies included were Fletcher (1972; 1978), Canning and Rose (1974), Oliver et al. (1985), Robbins and Klee (1987), St Louis and Ruscello (OSME-R) (1987). Duration measures in all five of the reviews were made using a hand-held stop watch. Only Fletcher (1972) used additional acoustic techniques (oscillographic) in an effort to make more precise timing measures. Cohen et al. (1998) observed that precise measurement of utterance durations is not possible with a stop watch, rather it requires the use of acoustic analysis equipment, to determine the onset and offset of the run of DDK repetitions. This advice was supported by Gadesmann and Miller (2008) from their study of DDK measurement in adult speakers with different neurological speech disorders. They reported poor inter- and intra-reliability ratings when DDK counts by time using a stopwatch and measurements using sound spectrograms were compared. They concluded that freely available instrumental software, such as Praat (Boersma & Weenink, 2001) may enable clinicians to supplement stopwatch recordings and thus enhance the reliability of DDK measurement. Murphy-Francis & Williams (2012) compared DDK rates produced by 28 typically-developing children aged 4-5 years, measured with a stop watch and with *Speech Filing System/Waveforms, Annotations, Spectrograms and Pitch* (SFS/WASP) (Huckvale, 2011). They reported significant differences in rates recorded by the two methods on bi-syllabic targets but not on tri-syllabic targets. Furthermore, they advised that the SFS/WASP was more helpful when dealing with some of the challenges involved in measuring DDK rates in young children such as false starts, pauses, production of additional targets, over-rapid productions and tester/child overlaps.

Cohen et al. (1998) noted that other factors are likely to have influenced reported DDK rates in the studies they examined. These include the method used to calculate DDK rate from the data, the chosen time measure, the choice of targets, the accents of the participants, the number of repetitions required and whether inaccurate as well as accurate productions are included in the calculations. Four of the five studies reviewed by Cohen et al. (1998) used a time-by-count method as proposed by Fletcher (1972). This records the time taken to produce a specified number of repetitions. In comparison, Robbins and Klee (1987) used a count-by-time method, i.e. the number of repetitions of a target produced in a specified time period (3 seconds in their study) are recorded. Robbins and Klee (1987) also reported rates in terms of the number of repetitions of the whole target per second, whereas other studies have reported rate in terms of syllables per second (e.g. Haselager et al., 1991; Yaruss & Logan, 2002). Cohen et al. (1998) advised the latter may be more useful as the DDK rates can be more easily compared with rates in imitated and spontaneous speech.

Since different consonant segments have different durational characteristics (Kent, 1994), the choice of target syllables is likely to influence reported DDK rates. Furthermore, the accents of individual speakers will affect the rate of production. Speakers of American and British varieties of English will use very different articulatory gestures to realise the second consonant in a sequence such as /pətəkə/ and this may affect performance rates. Therefore, rates produced by USA participants may not be readily transferred to UK participants. Kent et al. (1987) demonstrated this when they compared the normative rates from the studies by Fletcher (1972) and Canning and Rose (1974). There were considerable discrepancies in the rates produced by children at various ages. Kent et al. (1987) concluded that Fletcher's scores for American children aged 6-13 years were a conservative measure of normative performance, while Canning and Rose's scores for UK children aged 4;6-9;6 and 13;6-14;6 years were at the higher end of the normal range.

Normative DDK rates have been derived from different numbers of repetitions of target sequences. For example, for monosyllables, Fletcher (1972) used twenty repetitions, Canning and Rose (1974) used ten, and St Louis and Ruscello (1987) used sixteen. There is some debate as to whether or not this will affect the reported rates. For example, Haselager et al. (1991) reported that children aged 5-11 years produced faster rates in longer utterances. However, Walker and Archibald (2006) found that articulation rate in children aged 4-6 years was not affected by utterance length.

Studies have varied in whether they report DDK rates for only accurate productions or for both accurate and inaccurate productions. For example, Williams and Stackhouse (2000) included both correct and incorrect productions of the target when calculating DDK rate, but also measured accuracy separately. In comparison, Preston and Edwards (2009) calculated DDK rates based on all productions (accurate and inaccurate), in addition to accurate only productions. Cohen et al. (1998) observed that specific error types made by children may affect the DDK rates recorded. For example, voicing of a monosyllable such as /pə/ -> /bə/ may affect the number of repetitions produced; similarly substituting an alveolar stop for a velar stop may increase the number of repetitions produced, as velar gestures usually take longer to produce than alveolar gestures (Kent, 1994).

Yaruss and Logan (2002) recognised the differences in DDK rates in the literature but in keeping with Robbins and Klee (1987), concluded that preschool children can produce approximately one tri-syllable token (e.g. /ˈpətəkə/ or PATTICAKE) per second, and this increases to 1.5 tri-syllables per second by the age of 6 years.

2.3.2.8.iii DDK Measurement: Accuracy

Accuracy on DDK tasks has not always been measured directly in studies, although accuracy difficulties have been described, e.g. consonant sequencing errors. However, some studies have measured accuracy directly and independently of other measures. For example, Williams and Stackhouse (2000) utilised two measures of accuracy in their study of typically-developing children, aged 3-5 years: (a) accuracy of one repetition of the target, and (b) accuracy of five repetitions of the target. Consonant sounds only were compared to the adult model and scored by a binary method (right vs. wrong). Responses scored as incorrect included substitutions, omission of syllables, perseveration of a previous word, or cessation before the five repetitions were complete.

Graded binary methods for scoring DDK repetitions have also been used. For example, Robbins and Klee (1987) measured accuracy of mono-syllables and tri-syllables, using a 0-2 point scale: 0 points =absent function, 1 point =emerging function and 2 points =adult like function. However, further information concerning emerging function was not described. The scoring method on the DDK subtest of the Oro-motor Assessment of the DEAP (Dodd et al, 2002) also gives a graded binary score, 0-3 points for correct sound sequence, which is added to graded scores for fluency and intelligibility to give a total score. Maintaining the correct consonant sequence is also scored on the VMPAC (Hayden & Square, 1999) in addition to scoring for accuracy and precision of motor control during DDK production.

A different method of measuring accuracy was reported by Yaruss and Logan (2002) who reviewed transcripts of DDK productions from fifteen TD children, aged 3-7 years, with the aim of identifying deviations from the target consonants /p/, /t/, /k/. Six types of articulation errors were coded: insertions of sounds, deletions of sounds, changes in voicing, changes in placement, exchanges between sounds, and perseveration of sounds. Each term was defined and examples given (p. 71). Yaruss and Logan (2002) found that 80% (12/15) of their participants made deletion errors; 73% (11/15) made placement errors; and 53% (8/15) made voicing errors. The other types of articulation errors (exchanges, insertions and perseverations) occurred considerably less frequently. The articulation errors affected approximately 15% of the consonants in the trials, although there was considerable between- and within-subject variability. The authors concluded that their participants produced more errors on DDK productions than is typically expected in young children's conversational speech (Jaeger, 1992; Stemberger, 1989) suggesting that DDK tasks may be more motorically demanding than conversational speech for young children. Preston and Edwards (2009) subsequently used the coding system proposed by Yaruss and Logan (2002) to measure accuracy in their study of adolescents with and without speech difficulties.

2.3.2.8.iv DDK Measurement: Fluency

Yaruss and Logan (2002) also measured fluency of DDK productions in their study. They reported that very few disfluencies occurred in the transcripts of DDK productions of typically-developing children aged 3-7 years. Nevertheless, they concluded that measures of DDK accuracy and fluency are valuable adjuncts to rate and may provide useful information about children's speech development. Dodd et al. (2002) also include a graded fluency score, 0-3 points, in the DEAP DDK subtest, to capture whether children hesitate or have significant pauses during their DDK productions.

2.3.2.8.v DDK Measurement: Consistency

In their study of 3-5 year old TD children, Williams and Stackhouse (2000) recognised that the presence of typical developmental simplification processes reduced a child's accuracy scores when a comparison was made to an adult model. Therefore, they also scored each child's ability to repeat a target in a form consistent with their own sound system. The aim was to distinguish between children who use consistent patterns of simplification from those who are unable to sequence sounds and are inconsistent in their responses. For example, one child may repeat the adult model wrongly, but maintain the same production across five occasions (e.g. Target: BUTTERCUP, repeated as: /ˈbʌtətʌp/ and then as /ˈbʌtətʌp/, /ˈbʌtətʌp/, /ˈbʌtətʌp/, /ˈbʌtətʌp/), /ˈbʌtətʌp/while another may also repeat the target wrongly but then produce one or more different pronunciations of the target across five repetitions (e.g. BUTTERCUP: repeated as /ˈbʌtətʌp/ and then as /ˈbʌkətʌp/, /ˈbʌtətʌp/, /ˈtʌpəbʌk/, /ˈtʌpəbʌk/, ˈkʌpətʌp/. The number of times there was a set of five repetitions that all accurately matched the child's baseline production (rather than the adult model presented) was scored.

Williams and Stackhouse (2000) included a further rating of *consistency strength* which measured how many different versions of a target occurred within a run of five repetitions. It involved comparing each repetition of the target with the child's first baseline pronunciation (rather than the adult model). The following scale was used:

- Rating I - Repetition identical to child model

- Rating II - Repetition different from child model
- Rating III - Repetition different from either I or II
- Rating IV - Repetition different from all previous repetitions.

For each child, the number of items that reached a rating of I, II, III and IV in each of the RW, NW and SS conditions, and the totals across the conditions, were calculated.

Preston and Edwards (2009) and Preston and Koenig (2011) also included a consistency measurement to record the number of different versions produced in consecutive runs of ten repetitions by adolescents with persisting speech difficulties aged 10 to 14 and 9 to 15 years respectively.

2.3.2.8.vi DDK Instructions

As for any task, the instruction given for a DDK task is likely to influence performance. Therefore, in addition to the questions raised by Crary (1993) concerning stimuli and measurements of DDK, a third question needs to be added: What instructions will be given to the child? Most protocols for DDK tasks direct the child to 'say the sounds as fast as you can' and often include a model given by the tester. Another instruction often used is to 'keep going for as long as you can, until I tell you to stop' which may result in young children being unable to sustain the repetition task at maximum speed because they are intent on not missing the instruction to stop. Cohen et al. (1998) noted that:

> "The instructions given (and of course any materials involved) need very careful preparation in any protocol which is to be successful in eliciting DDK data from young children" (p. 430).

This view is supported by McCauley & Strand (2008) who observed that developing appropriate tasks when maximal performance is sought (e.g. for DDK rates) is especially difficult and particularly when the participants are young children whose attention, co-operation and understanding of the tasks requirements is uncertain (Davis & Velleman, 2000; Kent et al., 1987). For children 6 years and above, they suggest computerized presentations may help to address some of the motivational and measurement issues associated with maximal performance tasks (Rvachew, Hodge & Ohberg, 2005).

Following a review of DDK tasks, Cohen et al. (1998) proposed a new method of eliciting DDK data from pre-school children using a train set game. In this game, there is one engine and three coloured carriages – each represents one of the syllables (/pə/, /tə/, /kə/). The child is instructed that the driver 'needs to hear a special sound said again and again, clearly but as fast as you can because the train is running late today'. Different carriages were used to elicit the different mono-syllables and combinations of carriages were used to elicit the bi-syllabic and tri-syllabic sequences. A model was given to the child when s/he pulls the train. The therapist then takes the role of 'train puller' and the child is encouraged to produce the sequences until the therapist stops the train in order to encourage the child to sustain the repetitions. The authors trialled the use of this method successfully with 14 typically-developing children aged 3;10 - 4;11 and 14 children with phonological disorders aged 3;08-5;03. However, there have been no further published studies employing this method.

Other strategies used to support children in DDK tasks have been the use of a tick chart to help the child monitor how many times they had produced a target (Williams & Stackhouse, 2000), clapping games, as on the DEAP (Dodd et al. 2002), and the tester counting down the number of repetitions produced on their fingers. Each of the methods described has both advantages and disadvantages. For example, the train set game (Cohen et al., 1998) and the clapping game in the DEAP task (Dodd et al., 2002) are likely to appeal to young children. However, in the case of the clapping game, the child is required to perform an action whilst trying to produce rapid spoken repetitions and this could lead to a reduced rate of production and a loss of fluency. In the case of the train set game, the child may be reluctant to give up being the 'train puller' or could become so engrossed in the game that they lose interest in producing the DDK repetitions. The use of a tick chart can help the child keep track of the number of repetitions they have produced, however the child may wait for the tester to tick off each repetition and so slow their rate of production. This may also happen when the tester counts down the number of repetitions using their fingers and thumb, and /or the child may stop before all the fingers and thumb have been revealed. However, in both these two methods there is the advantage that the child is not required to carry out an action simultaneously with producing rapid spoken repetitions.

Issues about how to instruct children to repeat NWs in particular are also relevant to DDK tasks. Wells (1995), for example, advised that an instruction such as "I am going to say some strange/funny words that you won't have heard before. Try and imitate/copy exactly what I say", is likely to result in a child adopting a phonetic strategy in order to mimic the tester's pronunciation as closely as possible. In the case of young children around 4 years of age, this may extend to them attempting to imitate the word in the tester's accent, if it is different from their own. However, by 7 years of age they are more likely to repeat an unfamiliar target in their own accent (Nathan, Wells & Donlan, 1998). If the tester does not specifically instruct the child to try and copy exactly what s/he says, the child is likely to adopt a phonological strategy and repeat the targets in his/her own speech sound system, including their regional accent and stage of phonological development. Thus, the child is more likely to produce NWs accurately (in comparison with the adult model) after a spoken model if they are instructed to repeat them exactly as the tester produces them.

2.4 Summary of Main Findings from Literature Review 2

DDK skills are thought to reflect speech motor competence and therefore this chapter started with a detailed review of typical and atypical speech motor development. This was followed by a critique of approaches used to investigate speech skills, including DDK skills. Studies which have investigated DDK tasks have included different stimuli, measures, instructions and methods and have included children of different ages with differing speech presentations and severities. Furthermore, the performance of children with speech difficulties has not always been compared to that of typically-developing controls.

Thus, there is a need for a comprehensive DDK study to investigate the performance of a group of children with speech difficulties in comparison to that of a group of typically-developing children on a range of different types and lengths of stimuli, utilising a standard method and instructions and detailed evaluation on a number of different measures. DDK has been considered to be an oro-motor or speech motor measure, but the relationship between a child's DDK performance and their performance on other speech processing measures has not been explored in any detailed way to date. Therefore, the study should also investigate the performance of the children with speech difficulties on a range of speech processing measures and compare and contrast their performance on DDK tasks with their performance on these other measures.

2.5 Research Questions

The following research questions were formulated for the current study:

1. How do a group of children with speech difficulties (aged 4-7 years) perform on DDK tasks when (a) Accuracy, (b) Consistency and (c) Rate are measured?
2. How does the performance of the group of children with speech difficulties on DDK tasks compare to that of a group of age-matched typically-developing children?

3. Within the group of children with speech difficulties, is there a relationship between DDK accuracy and (a) DDK consistency, and (b) DDK rate?
4. Is there a relationship between DDK measures and other speech processing measures for the children with speech difficulties?
5. Is it possible to identify individual DDK profiles of accuracy, consistency and rate in the group of children with speech difficulties, in comparison to age-matched typically-developing children?
6. Can children with the same DDK profiles be regarded as forming distinct subgroups within the group of children with speech difficulties?

Chapter three will present the method for addressing the above research questions.

Chapter Three
Method

3.1 Design

A group study design was adopted to investigate the diadochokinetic (DDK), speech and oro-motor skills of 40 children, aged 4-7 years, with speech difficulties, who had been assessed by a speech and language therapist (SLT) and who were receiving intervention targeting their speech. As the aim was to include children who had speech difficulties of differing severity, participants were recruited who were attending speech and language therapy in either a primary care NHS setting where a range of children are seen and at a specialist NHS centre for children with speech difficulties. The children attending this specialist NHS centre had already been assessed and had received intervention from local SLTs prior to being referred on for further assessment and intervention due to concerns over the severity or persistence of their speech difficulties. The SLTs in the primary care setting were asked to propose children who met the inclusion criteria, but who had mild to moderately-severe speech difficulties.

In addition to these children with speech difficulties, typically-developing children aged 4, 5, 6, 7 years were also recruited to provide control data for the non-standardized DDK tasks and the mispronunciation detection task.

3.2 Ethical approval

Approval to carry out this study was obtained from the National Health Service (NHS) National Research Ethical Service (REC reference: 10/H0718/39) on 08.07.10 (see Appendix 3.1) and from the Research and Development departments of the Royal Free (Hampstead) NHS Trust (Project ID: 8094) on 20.01.11. (see Appendix 3.2) and from Hertfordshire Community NHS Trust on 28.05.12. (see Appendix 3.3). Ethical approval to collect data from typically-developing participants was obtained from University College London (UCL Ethics Project ID Number: 0984/002) in December 2009.

3. 3 *Participants*

3.3.1 Recruitment of children with speech difficulties

SLTs working in the two settings were asked to propose children who met the following criteria:

- Chronological age 4-7 years
- Current speech difficulties (as identified by speech and language therapist) and receiving intervention targeting speech).
- No known current hearing difficulties (as reported in speech and language therapy notes).
- English as primary language spoken at home (as reported in speech and language therapy notes).
- Typical or only mildly delayed understanding of spoken language (as identified by speech and language therapist and reported in case notes).
- Expressive language developed to at least a 3-4 word level[7] (as identified by speech and language therapist and reported in case notes).
- No concern regarding cognitive development (as reported in speech and language therapy notes).

Brief information about the study was given verbally to parents by their child's SLT, following guidance from the author. This was supported by detailed written information about the study, which was sent home for parents to read. Parents were asked to sign a consent form to give permission for their child to participate in the research. In addition, verbal assent was obtained from each child, before any assessment tasks were commenced.

3.3.2 Children with speech difficulties recruited

Forty children with speech difficulties, aged 4-7 years, who were all receiving speech and language therapy intervention targeting their speech, were recruited. They included 30 boys and 10 girls in the age range of 4 years 1 month to 7 years 10 months (see table 3.1). The age and gender distributions were limited by the availability of participants, who met the inclusion

[7] Children were not required to have age appropriate expressive language skills. However, their expressive language skills were required to be developed to at least a 3-4 word level, in order to be able to complete some of the tasks.

criteria, in the two speech and language therapy settings (one primary and one specialist). The children with speech difficulties recruited were:

- children with isolated articulation difficulties, isolated phonological difficulties and combinations of articulation and phonological difficulties - details for individual children are given in Appendix 8.10 Linguistic classification. Furthermore, they included children with resolving speech difficulties who had had more severe speech difficulties in the past – case details for individual children are given in Appendix 8.12 WHO ICF–CY classification under Personal and environmental factors.

- children with both unknown and known aetiologies which may be contributing to their presenting difficulties – case details of individual children are included in Appendix 8.12 WHO ICF-CY classification under Body Structures and Body Functions.

- children with no current hearing difficulties identified by their speech and language therapists. However, there were a small number of children in the group who had a history of past hearing difficulties – case details for individual children are given in Appendix 8.12 WHO ICF-CY classification under Personal and environmental factors.

- children who were growing up in an environment where more than one language is spoken as well as children growing up in a monolingual home environment – case details for individual children are given in Appendix 8.12 WHO ICF-CY classification under Personal and environmental factors. However, in all cases, English was reported to be the main language spoken at home.

- children with a history of language difficulties as well as children with persisting expressive language difficulties – case details are included in Appendix 8.12 WHO ICF-CY classification under Personal and environmental factors and under Activity and Participation. However, in all cases their speech and language therapists considered their current receptive language to be within the normal range and their expressive language developed to at least a 3-4 word level.

- children where no concern had been raised or reported in speech and language therapy notes about their general cognitive functioning.

The characteristics of the children from the primary and specialist settings are listed in table 3.1.

Table 3.1 Summary of characteristics of the children recruited from the primary and specialist settings.

	Primary setting	Specialist setting
Chronological age 4-7 years	✓	✓
Current isolated articulation difficulties	✓	✓
Current isolated phonological difficulties	✓	
Current combined articulation and phonological difficulties	✓	✓
Resolving speech difficulties but still requiring intervention	✓	✓
Known aetiology	X	✓
Unknown aetiology	✓	✓
History of hearing difficulties	✓	✓
Current expressive language difficulties, but developed to at least a 3-4 word level	X	✓
History of expressive language difficulties	✓	✓
Monolingual home environment	✓	✓
Bilingual/trilingual home environment but with English as main language spoken at home	✓	✓
Receiving intervention delivered directly by SLT	✓	✓
Receiving intervention delivered by SLTA, under direction of SLT	✓	X

Key: ✓ = children who met this criterion; X = children who didn't meet this criterion; SLT=Speech and language therapist; SLTA=Speech and Language Therapy Assistant.

In order to investigate whether the children with speech difficulties could be considered a group, two correlational analyses were administered to examine whether any relationship existed between (a) age (measured in months) and severity of speech difficulties (measured by percentage of consonants correct (PCC) on the DEAP Phonology test (Dodd et al., 2002); and (b) gender and severity of speech difficulties (measured as above). Neither correlation (using Spearman's rho) was statistically significant: age (r =.309) and gender (r =.522). The forty children were therefore regarded as a group, and are referred to as the clinical group from here on.

3.3.3 Recruitment of typically-developing children

These children were all attending mainstream schools or nurseries in S.E. England. School staff were asked to identify children who met the following inclusion criteria:

- Apparent typical development
- No known current hearing difficulties
- No known current or historical speech and language difficulties
- English as primary language spoken at home

Written information was given to parents and they were asked to sign a consent form giving consent for their child to participate in the study.

3.3.4 Typically-developing children recruited

Forty typically developing 4-7 year old children with no known current or historical speech and language difficulties and who met the other inclusion criteria were recruited and matched by age to the clinical children. The group included 21 boys and 19 girls and the age range was 4 years 4 months to 7 years 6 months (see table 3.2). The typically-developing children were recruited independently of the clinical children (rather than by any pre-planned matching) and the availability of participants was restricted by the willingness of the schools/nurseries to participate and by parental consent.

Table 3.2 Distribution of the clinical and typically-developing children by age, in years and months, and by gender.

	4;0-4;11 years	5;0-5;11 years	6;0-6;11 years	7;0-7;10 years	Totals
Clinical Male	8	13	7	2	30
Clinical Female	2	7	1	0	10
Clinical Total	**10**	**20**	**8**	**2**	**40**
TD Male	7	7	4	3	21
TD Female	4	10	5	0	19
TD Total	**11**	**17**	**9**	**3**	**40**

Key: TD=Typically-developing.

3.4 Data collection

All the clinical data was collected by the author, an experienced, consultant SLT. The typically-developing data was collected by three speech and language therapy students who were supervised by the author.

Audio recordings were made of the clinical children using a Marantz professional solid state recorder PMD 661. Audio recordings of the typical children were made using a digital recorder M-AUDIO Microtrack 24/96 and an external microphone Sony ECM-MS907 (for the 4 and 5 year old children) and a digital recorder Roland R-09HR (for the 6 and 7 year old children). In addition, video recordings, using a Sony Handycam HDRP J10E, were made of the clinical children. The audio and video recordings were used for data analysis, after the testing.

3.5 Tasks, Targets and Materials

All the children (clinical and typically-developing) completed a mispronunciation detection task as well as three different DDK tasks with matched targets and presentation, modified from Williams (1996) and reported in Williams and Stackhouse (2000). The clinical children were also assessed on a number of other tasks as identified in table 3.3 below.

Table: 3. 3 Tasks completed by the typical and clinical children.

Task	Typical children	Clinical children (primary setting)	Clinical children (specialist setting)
Mispronunciation Detection	✓	✓	✓
DDK: Real words (RW)	✓	✓	✓
DDK: Non-words (NW)	✓	✓	✓
DDK: Syllable Sequences (SS)	✓	✓	✓
DEAP Oro-motor Assessment: Isolated Movements (IM)	X	✓	✓
DEAP Oro-motor Assessment: Sequenced Movements (SM)	X	✓	✓
Single consonant & vowel imitation task	X	✓	✓
DEAP Phonology Assessment	X	✓	✓
Informal picture description task	X	✓	✓
DEAP Inconsistency Assessment	X	X	✓

Key: ✓= carried out task; X =did not carry out this task; DEAP= *Diagnostic Evaluation of Articulation and Phonology (DEAP)* (Dodd et al., 2002).

3. 5.1 DDK Tasks: Timed real word repetition

The children were asked to imitate the tester's production of ten familiar two and three syllable words (2 practice and 8 test items), such as MONEY and PATACAKE, and then repeat each word five times at speed (see Appendix 3.4 for a full list of the test items and Appendix 3.5 for a list of the consonant segment distribution). A picture naming/familiarisation task, presented via a PowerPoint presentation on a laptop computer, was included prior to administering this task to ensure the words were known to the children, i.e. to check that they had lexical representations for the items. The pictures were also used in the administration of the timed real word (RW) repetition task to support the children's attention while being tested and to stimulate lexical support for the task. This was therefore a top-down task, where prior linguistic knowledge of the word facilitates repetition performance. The child was required to access a stored motor programme for the word in order to repeat it once and then motor planning skills in order to repeat the same word on five consecutive occasions.

The ten words were selected from the original twenty-two words used in the study by Williams (1996) and reported in Williams and Stackhouse (2000). Four of the chosen words were 2 syllables in length and had different consonants in first and second syllable initial position (e.g. MONEY, DIGGER) and four were 3 syllables in length and had different consonants in all three syllable initial positions (e.g. PAT-A-CAKE, TELEPHONE). The words chosen included long, short and diphthong vowels and consonant segments from different phonetic classes: plosives /p,b,t,d,k,g/, nasals /m,n/, approximants /l/ and fricatives /f/. The two practice items involved one example of a two syllable word and one of a three syllable word. (See Appendix 3.4 for a full list of the targets included and Appendix 3.5 for a distribution of the consonant segments for each of the eight real word, non-word and syllable sequence targets). The ten items were represented by coloured pictures taken from the CD supplied with the *Compendium of Auditory and Speech Tasks* (Stackhouse et al., 2007).

3. 5.2 DDK Tasks: Timed non-word repetition

The children were asked to imitate the tester's production of ten made up two and three syllable non-words (2 practice and 8 test items), such as [ˈmɪnə] and [ˈpɒtɪkəʊk], and then repeat the same non-word (NW) five times at speed (see Appendix 3.4 for a full list of the test items and Appendix 3.5 for a list of the consonant segment distribution). Unlike in the RW repetition task, there is no stored motor programme for the test items since all the words are unfamiliar. The NW repetition task requires the child to assemble a new motor programme in order to repeat it once, and motor planning skills to repeat the new word on five consecutive occasions.

Ten NWs which matched the ten RWs, in 3.5.1 above, were selected from the original twenty-two items used in the study by Williams (1996) and reported in Williams and Stackhouse (2000). These NWs were derived from the RWs by maintaining the consonant sequence, but changing the vowels. Vowel length was maintained but alternative short vowels were substituted for the short vowels in the RWs, and alternative long vowels /diphthongs were substituted for the long vowels in the RWs, for example DIGGER became [ˈdægɪ] and CARDIGAN became [ˈkudægən]. The stress patterns matched those of the RWs. Since these items are NWs, there were no supporting picture cues.

3. 5.3 DDK Tasks: Timed syllable sequence repetition

The children were asked to imitate the tester's production of ten nonsense, two and three syllable sequences (2 practice and 8 test items), such as [ˈməˈnə] and [ˈpəˈtəˈkə], and then repeat the same syllable sequence (SS) five times at speed (see Appendix 3.4 for a full list of the test items and Appendix 3.5 for a list of the consonant segment distribution). As no syllable is presented with any more stress than the others, the stimuli are illegal NW targets in English. This was therefore a non-lexical task (bottom-up) which assessed the children's articulatory and speech motor planning skills.

Ten SSs were selected from the original twenty-two used in the study by Williams (1996) and reported by Williams and Stackhouse (2000), in order to match the ten RWs and NWs in the tasks above. The SSs were derived from the RW and NW stimuli by maintaining the syllable initial consonant sequence, but substituting a schwa /ə/ for each vowel e.g. DIGGER became [ˈdəˈgə] and CARDIGAN became [ˈkəˈdəˈgə]. They were presented with equal stress. Since these items are meaningless, there were no supporting picture cues.

3. 5.4 Mispronunciation detection task

The children were asked to participate in a mispronunciation detection task (MDT), to investigate the accuracy of their phonological representations for the 2 and 3 syllable words included in the DDK tasks. The task was presented using the SIPc software (Vance et al., 2009). Each child looked at a computer screen with a picture of a castle on each side of the screen and a boy's face above each castle (see Figure 3.1). The child was told and shown that the boy on the left says words correctly but the boy on the right (marked with a large red cross) sometimes 'gets them a bit wrong'.

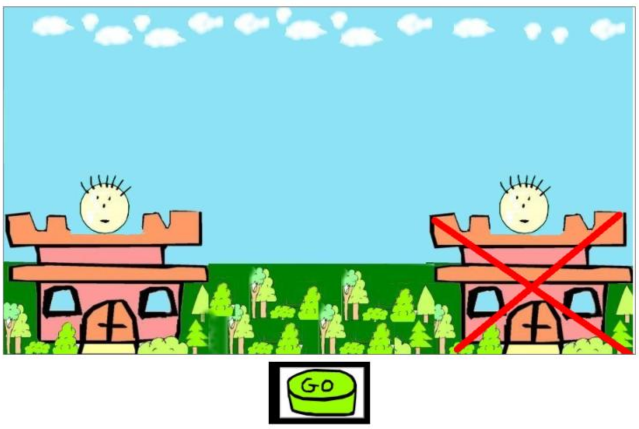


Figure 3.1 Screen shot of SIPc used to introduce the MDT task.

A picture appeared in the middle of the screen and the child heard a word, spoken correctly or incorrectly, e.g. picture of a cardigan appeared (see Figure 3.2). and child heard a correct pronunciation of cardigan or an incorrect one such as ['pækəkeɪk]. The child's task was to select whether the word heard was said correctly or not by selecting the boy on the left or the boy on the right. The computer programme provided verbal feedback after each item, such as 'well done' or 'try again', and visual feedback by adding a small balloon picture to a stack on the left hand side of the screen after each correct production. Once a stack of fifteen balloons had been achieved, the child received a reward of watching/listening to a short cartoon sequence.

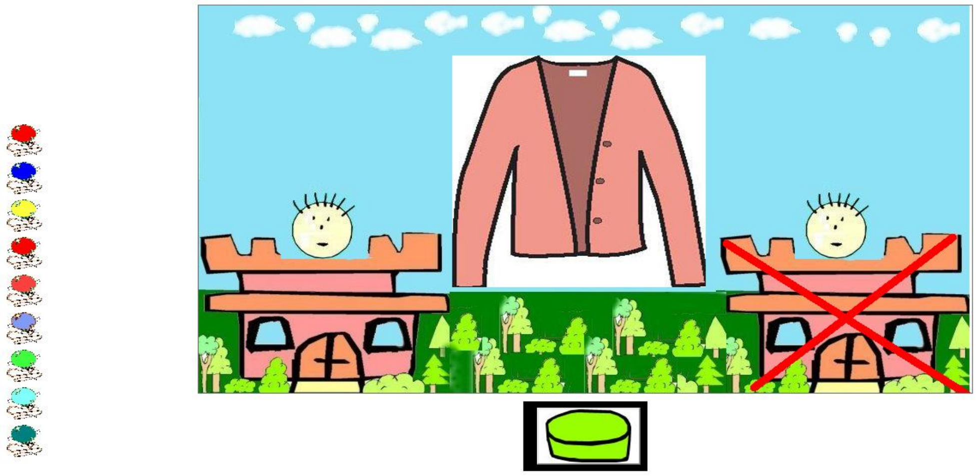


Figure 3.2 Screen shot of SIPc during a test block, for target: CARDIGAN. The child was asked to wear Sennheiser HD202 over-the-ear headphones to allow optimal listening conditions. After a short computer familiarisation task and a picture selection vocabulary check (see Appendix 3.6 for a full list of targets included), the task was trialled in a practice block involving 15 items. Once complete, the main test was administered. The children saw 60 pictures (divided into 4 blocks of 15 items, with simple rewards after each block) in a PowerPoint presentation on a computer screen and they heard a word spoken either with a typical pronunciation or with one of the sounds changed to create a mispronunciation, for example for the target: PAT-A-CAKE, typical pronunciation [ˈpætəkeɪk]; the mispronunciations created were ['pætət̲eɪk], ['pæk̲ət̲eɪk], ['pæk̲əkeɪk], ['pætəkə̲ʊ̲k], ['pɒ̲təkeɪk] (see Appendix 3.7 for a full list of the created mispronunciations). Across the four blocks, the child heard three correct and four incorrect, manipulated versions of the two syllable words and three correct and five incorrect,

manipulated versions of the three syllable words. The test items were randomised across the four blocks.

The targets for this task comprised the four 2 syllable and four 3 syllable words used in the DDK tasks and manipulated versions of those words. The manipulated versions mirrored errors made by children with speech difficulties on DDK tasks (See Appendix 3.7 for a full list of all the items created). They included perseveration of a consonant (e.g. CARDIGAN produced as [ˈkɑɡɪɡən]); transposition of two consonants (e.g. PAT-A-CAKE produced as [ˈpækəteɪk]); manner or voice change to a consonant (e.g. MONEY produced as [ˈmʌlɪ]; PARTY produced as [ˈbɑtɪ]); or a vowel change (e.g. PAT-A-CAKE produced as [ˈpætəkəʊk]). The correct and manipulated targets were spoken by the author, a female Southern British English speaker and recorded in an Anechoic chamber and subsequently incorporated into the SIPc software (Vance et al., 2009).

The picture selection vocabulary check administered prior to the mispronunciation task ensured the child was familiar with the pictures and could select a target from a choice of four. Each set of four pictures involved a word semantically similar to the target word, a word with the same onset sound to the target and a word with the same syllable structure. For example, for the target word DIGGER, the other three pictures were TRACTOR (semantically similar), DINOSAUR (same onset sound), TIGER (same syllable structure); and for the target word PAT-A-CAKE, the other three pictures were GLOVE (semantically similar), POTTY (same onset), BUTTERCUP (same syllable structure). (See Appendix 3.6 for a list of the full set of items used). The pictures for the vocabulary check and the mispronunciation detection tasks were taken from the CD supplied with the *Compendium of Auditory and Speech Tasks* (Stackhouse et al., 2007).

3.5.5 Assessment of oral skills

Two subtests of the Oro-motor Assessment from the DEAP (Dodd et al., 2002) were administered to the clinical children: Isolated Movements and Sequenced Movements. The child is required to execute four single non-speech oral movements (e.g. Can you spread your lips like this?), and three sequenced non-speech oral movements (e.g. can you kiss and cough?). The instructions for administering the subtests given in the DEAP manual (p. 20-21) and on the Oro-motor Assessment record sheet were followed. For each target, the tester gave the children a verbal instruction and a demonstration.

3.5.6 Single consonant and vowel sound imitation tasks

The clinical children were asked to imitate the 24 single consonant sounds and the 18 long, short and diphthong vowels of Southern British English.

3.5.7 Assessment of Phonology

The clinical children were assessed on The Phonology Assessment from the DEAP (Dodd et al., 2002), following the instructions given in the manual (p.22 and p.24). Fifty coloured pictures of A5 size were presented one at a time to each child as a naming task. The pictures depict words of one to four syllables in length and test consonant and vowel sounds in different positions in words (initial, medial and final) and include singleton and cluster realisations. In accordance with the manual (p.22), semantic or forced choice cues were used to elicit the words, as necessary. The subtest also includes 3 plates of 'funny pictures' designed to stimulate connected speech and the child was asked: '*What is funny about the picture*?' or '*What is happening in the picture*?'

3.5.8 Assessment of word consistency

The clinical children attending the specialist centre were assessed on the Inconsistency Assessment from the DEAP (Dodd et al., 2002). Following the instructions given in the DEAP manual (p.25), they were required to name 25 single A5 size coloured pictures on three different occasions within the same test session but with other tasks carried out in between. As in the DEAP Phonology Assessment above, semantic or forced choice cues were used to elicit the target words if the child was unable to name the pictures. Due to time restraints, this task could not be administered to the children in the primary care setting.

3.5.9 Assessment of connected speech

To supplement the connected speech utterances obtained from the DEAP Phonology Assessment above, the clinical children were also asked to describe five 'What's wrong cards?' (LDA) e.g. a picture of a duck wearing wellington boots; a picture of an aeroplane with bird wings. Samples from this data were used to measure speaking rate.

3.6 Procedure

3.6.1 Pilot with children with speech difficulties

Prior to the main study, the tasks, materials and procedures were piloted on one four year old child and one ten year old child. Following the pilot, it became clear that it was difficult for the tester to administer the tasks and keep the child interested and motivated, whilst simultaneously making audio and video recordings. It was therefore decided to request that parents, who accompanied the child to the data collection sessions or SLTs/SLTAs made the video recordings during the sessions.

3.6.2 Children with speech difficulties in the specialist NHS setting

Each child was seen individually for two assessment sessions, each of around 45 - 60 minutes duration. At the beginning of the first session, the tester used the Information sheet prepared for children to give them a simple verbal explanation of the tasks supported by pictures, and the child's assent was obtained. The tasks were distributed across the two sessions to help maintain motivation and interest and to avoid fatigue and tiredness effects. Praise was given for effort and simple rewards were given between tasks, e.g. stickers, playing with a toy or watching a short visual clip on the computer.

The planned order in which the tasks would be administered is listed below. However, given the young age of the children being tested there was some required variation of task order in order to maintain their co-operation and motivation.

Session 1: The Mispronunciation Detection Task (MDT) and the DEAP Inconsistency Assessment.

- MDT: Picture naming/familiarisation task and computer familiarisation task
- MDT: Picture selection vocabulary check
- MDT: Practice and Block 1
- DEAP Inconsistency (1)
- MDT: Block 2
- DEAP Inconsistency (2)
- MDT: Block 3
- DEAP Inconsistency (3)
- MDT: Block 4

Session 2: The DDK Tasks, the DEAP Oro-motor Assessment (2 subtests), the DEAP Phonology Assessment, the single sound imitation tasks, and the informal picture description task.

- Single consonant and vowel sound imitation tasks
- DDK task (1)
- The DEAP Phonology Assessment and the informal picture description task
- DDK task (2)
- The DEAP Oro-motor Assessment (2 subtests)
- DDK task (3)

3.6.3 Children with speech difficulties in the primary care NHS setting

The data collection in the primary care NHS setting took place after the data collection at the specialist centre. The tasks were described to the children at the beginning of the first session as they were for the children in the specialist setting, and similar praise and rewards were given. Each child was seen individually for two assessment sessions, but the sessions were shorter for this group, 40 - 50 minutes duration, since the DEAP Inconsistency assessment was not administered, due to time constraints. The tasks were administered as follows:

Session 1: The Mispronunciation Detection Task (MDT) and the single sound imitation tasks

- MDT: Picture naming/familiarisation task and computer familiarisation task
- MDT: Picture selection vocabulary check
- MDT: Practice and Block 1
- Single consonant sound imitation task
- MDT: Block 2
- Single vowel sound imitation task
- MDT: Blocks 3 and 4

Session 2: The DDK Tasks, the DEAP Oro-motor Assessment (2 subtests), the DEAP Phonology Assessment and the informal picture description task.

- DDK task (1)
- The DEAP Phonology Assessment and the informal picture description task
- DDK task (2)
- The DEAP Oro-motor Assessment (2 subtests)
- DDK task (3)

3.6.4 Typically-developing children

Children were tested individually in their nursery or schools. The DDK tasks and the mispronunciation detection task were administered in one session of approximately 45 minutes duration.

3.6.5 Procedure for administering the DDK tasks

For the three DDK tasks, each child was randomly assigned to receive the tasks in one of the following orders: ABC, BCA or CAB, where A = real words, B = non words and C = syllable sequences. Within each DDK task, the order of presentation of the two and three syllable items was randomised, to avoid fatigue effects.

3.6.5.1 DDK Tasks: real words

Using the Microsoft Office powerpoint presentation, the tester named each picture in turn and asked the child to imitate the name. After the child had imitated the target once, s/he was then asked to say it five times, as quickly as possible, e.g. target item MONEY was imitated once /ˈmʌnɪ/ and then said five times: /ˈmʌnɪ, ˈmʌnɪ, ˈmʌnɪ, ˈmʌnɪ, ˈmʌnɪ/. This procedure was followed for each of the test items. The tester 'marked off' each production by holding up her right hand and revealing a finger or thumb. When the child could see all four fingers and the thumb, the required number of repetitions had been produced. If this method was unsuccessful, a tick chart was used to help the child monitor how many times they had produced a word. This comprised five boxes per item and the tester ticked a box every time the child made a response. Full instruction details are given in Appendix 3.8. Feedback was given on the two practice items to ensure the child understood the task. For example, if the child stopped after three or four repetitions, s/he was encouraged to continue for longer; if the child went so fast that the item lost any recognized form, s/he was reminded that the tester needed to hear the word; if the child went very slowly, s/he was asked to try again but faster. No help was given with the test items. A stopwatch was used during the testing procedure to help the children understand the task. However, the actual rates included in the data analysis were timed objectively from the audio recordings using Praat (Boersma & Weenink, 2001).

3.6.5.2 DDK Tasks: non-words

The tester explained to the child that the words were not real words and that s/he would not have heard them before. The aim of the game was to imitate the tester's model once. For the younger children, the task was modified as required, by introducing a toy monkey who asked the child to say some 'monkey words'. In this scenario, the aim of the game was to imitate the monkey's production once. In both cases, the procedure then followed that of the timed RW repetition above: following one imitation of each target NW, the child was asked to say the NW item five times as quickly as possible. The child was supported by the tester 'marking off' the repetitions using her fingers and thumb as described under RW repetition, or by using a tick chart if this was unsuccessful. The aim was for the child to know when they had produced five repetitions. Full instruction details are given in Appendix 3.8. Again a stopwatch was used during the live recording to facilitate the children's understanding that speed was required in this task. However, as for RWs, the rates included in the data analysis were timed objectively from the audio recordings using Praat (Boersma & Weenink, 2001).

3.6.5.3 DDK Tasks: syllable sequences

Each child was asked to imitate the tester saying some 'sounds'. Help was given with the practice items but not the test items. After the target had been imitated once, the child was asked to say it five times as quickly as possible. The same procedure was followed as described under RWs and NWs above to enable the child to know when they had produced five repetitions. Full instruction details are given in Appendix 3.8. As for RWs and NWs, a stopwatch was used during the testing but the rates included in the data analysis were calculated using Praat (Boersma & Weenink, 2001).

3.7 Scoring

3.7.1 Scoring of DDK tasks

Two measures of accuracy, two measures of consistency and one measurement of rate were made following Williams (1996) and reported by Williams and Stackhouse (2000). Additional measures of accuracy were also included in the current study.

3.7.1.1 Binary scoring: Accuracy of a single repetition of the target compared to the adult model

Each child's attempt at imitating the target (RWs, NWs and SSs) once was transcribed from audio/video recordings using IPA symbols and diacritics. Only consonant sounds were scored (see Appendix 3.9 for a scoring sheet example). Criteria were set to determine if the child had produced a correct or incorrect production (see table 3.4). A binary scoring method was used: 1 point for a production, which met each of the four correct criteria and 0 point if any one of the incorrect criteria occurred.

Table 3.4 Criteria used to determine if the child's single imitation response was correct or incorrect.

Correct	**Incorrect**
First attempt	Attempt other than first attempt
Modelled target produced	A different target produced
Correct number of syllables produced	Syllable omissions occurred
Consonants produced as in adult model -no deletion or addition errors and no substitution errors other than minor allophonic variants e.g. dental productions of /s/ and /z/.	Consonants not produced as in adult model –deletion, addition, or substitution errors occurred.

Careful consideration was given to whether a glottal stop should be accepted when it is used to replace a voiceless alveolar plosive at the onset of a second or third unstressed syllable. Examination of the typically-developing data, collected in a similar geographical location to the clinical settings, indicated that these children rarely used glottal stops in an imitation task but appeared to adhere to the instruction to say the target as the tester had modelled it. In contrast, several of the clinical children produced a high number of glottal stops throughout their speech samples (e.g. they used a glottal stop to replace /t/ in PARTY, PAT-A-CAKE and LETTERBOX). Since this presentation was very different to that of the typically-developing children, it was decided to score use of [ʔ] as incorrect, when used to replace a voiceless alveolar plosive at the onset of a second or third unstressed syllable.

3.7.1.2 Binary scoring: Accuracy of five repetitions of the target compared to the adult model

Each child's production of five repetitions of the targets in each of the three conditions (RWs, NWs, SSs), was transcribed from audio/video recordings using IPA symbols and diacritics. Again, only consonant accuracy was scored using similar criteria to those used for single repetitions (see 3.7.1.1), but with the additional criterion that where the child stopped before the run of five repetitions were complete, responses were scored as incorrect. The binary scoring method used was: 1 point for a set of five correct repetitions, which met each of the five correct criteria, and 0 point for a set which included one or more incorrect productions. Table 3.5 lists the criteria used to determine correct vs. incorrect production.

Table 3.5 Criteria used to determine if the child's set of five repetition responses were correct or incorrect.

Correct	**Incorrect**
First attempt	Attempt other than first attempt
Modelled target produced	A different target produced
Produced run of 5 repetitions	Stopped before 5 repetitions were produced
Correct number of syllables produced	Syllable omissions occurred
Consonants produced as in adult model -no deletion or addition consonant errors and no substitution errors other than minor allophonic variants e.g. dental productions of /s/ and /z/.	Consonants not produced as in adult model –deletion, addition, or substitution errors occurred.

Further consideration was given to glottal stop replacements in this task, which was less reliant on immediate repetition after an adult model. It was noted that within a run of five repetitions, some of the typically-developing children produced both /t/ and [ʔ] in an unstressed syllable onset position. For example, the target LETTERBOX was repeated five times by a typically-developing child as follows: [ˈlɛtəbɒks], [ˈlɛtəbɒks], [ˈlɛʔəbɒks], [ˈlɛʔəbɒks], [ˈlɛtəbɒks]. This demonstrated that the child could use /t/ in unstressed syllable onsets and it was therefore decided to accept glottal replacements as correct, for both the typically-developing and clinical children, when they occurred in this way. However, where glottal replacements were used in each of the five repetitions, these were scored as incorrect.

3.7.1.3 Percentage Consonants Correct (PCC): Accuracy of one repetition of the target and accuracy of five repetitions, compared to the adult model

The transcribed utterances for single and five repetitions were scored for PCC based on the following formula: Total consonants correct /total consonants elicited x 100 (see Appendix 3.10 for scoring example). Some of the children (particularly in the clinical group) stopped before a run of five repetitions was complete and therefore scored 0 points on the Accuracy measure described in 3.7.1.2. However, they could still score on the PCC Accuracy measure based on the number of consonants which they did produce.

As described under 3.7.1.1. and 3.7.1.2, consonants were deemed to be correct if they replicated the adult model and contained no deletion or addition errors nor substitution or distortion errors beyond minor allophonic variants. A separate calculation was made of the number of consonant errors in terms of place, manner and voice and of any consonant transpositions and perseverations.

3.7.1.4 Binary scoring: Consistency of five repetitions compared to the child's own baseline production

The child's first imitated response of each target was taken as the baseline in each of the conditions (RWs, NWs, SSs), irrespective of whether it was accurate compared to the adult model. A binary scoring method was used: 1 point for a set of five repetitions that matched the child's baseline production (regardless of accuracy compared to the adult model) and 0 for a set which included one or more versions, which differed from the child's baseline production (see table 3.6 for an example). The scoring procedure was, therefore, the same as described under 3.7.1.2 Accuracy of five repetitions, but the child's baseline production was taken as correct rather than the adult model (see Appendix 3.9 for scoring sheet example).

Table 3.6 Examples of binary scoring for Consistency of five repetitions.

Target	Child's 1st attempt	Repetition 1	Repetition 2	Repetition 3	Repetition 4	Repetition 5	Score
[ˈdɪgə]	[ˈdɪdə]	[ˈdɪdə]	[ˈdɪdə]	[ˈgɪgə]	[ˈgɪgə]	[ˈgɪgə]	0pt.
[ˈtɒləfaɪn]	[ˈtɒdəfaɪn]	[ˈtɒdəfaɪn]	[ˈtɒdəfaɪn]	[ˈtɒdəfaɪn]	[ˈtɒdəfaɪn]	[ˈtɒdəfaɪn]	1pt.

3.7.1.5 Consistency strength rating of five repetitions

A consistency strength rating measured the consistency of the children's speech production on the DDK repetition tasks, within their own speech sound system. The aim was to assess whether the child produced a target consistently i.e. in the same way as their first imitated response (baseline production) and on each of the five repetitions, or whether they produced a target inconsistently i.e. by producing more than one version, in comparison to their first imitated response (baseline production), within the run of five repetitions.

Each repetition of a target was compared to the child's baseline production and across the other four repetitions of the same target. As in the other measures, only consonants were scored. The following rating scale was used based on the description in the *Compendium of Auditory and Speech Tasks* (Stackhouse et al., 2007) in chapter 7, pages 163-4).

Rating 0: No repetition produced.

Rating 1: Repetition identical to child's baseline production (i.e. their first imitated response).

Rating 2: Repetition different from child's baseline production.

Rating 3: Repetition different from child's baseline production and from one other previous repetition.

Rating 4: Repetition different from child's baseline production and from two other previous repetitions.

For each target, the highest number reached across the run of five repetitions was recorded (see tables 3.7i, ii and iii for examples). The number of targets that reached a rating of 0, 1, 2, 3 and 4 across the RW, NW and SS conditions, were added together to give an individual child's total rating scores (see Appendix 3.9 for scoring sheet example). The sets of individual scores which reached ratings 0, 1, 2, 3, 4 from the clinical children were combined and compared to the sets of combined scores from the typical children in the between group analyses.

Table 3.7i Consistency strength scoring example:

For the target: [ˈpəˈtəˈkə], the child's baseline production is: [ˈpəkəkə]. For the five repetitions the child produces:

Child's baseline	ˈpəkəkə	Rating	Definition of rating
1st Repetition	ˈpəkəkə	1	Repetition identical to child's baseline production.
2nd Repetition	ˈpəkəkə	1	Repetition identical to child's baseline production.
3rd Repetition	ˈpəkəkə	1	Repetition identical to child's baseline production.
4th Repetition	ˈkʊkəbə	2	Repetition different from child's baseline production.
5th Repetition	ˈkʊkəbə	2	Repetition identical to 4th repetition but different from child's baseline production and from 1st, 2nd & 3rd repetitions.
Rating recorded for target		2	

Table 3.7ii Consistency strength scoring example:

For the target: [ˈkəˈdəˈgə] the child's baseline production is: [ˈkəˈdəˈŋgə]. For the five repetitions the child produces:

		Rating	Definition of rating
Child's baseline	[ˈkəˈdəˈŋgə]		
1st Repetition	[ˈdəˈgəˈgə]	2	Repetition different from child's baseline production.
2nd Repetition	[ˈdəˈgəˈnə]	3	Repetition different from child's baseline production and from one other previous repetition (i.e. the 1st repetition).
3rd Repetition	[ˈdəˈgəˈnə]	3	Repetition identical to 2nd repetition but different from child's baseline production and from one other previous repetition (i.e. the 1st repetition).
4th Repetition	[ˈdəˈgəˈnə]	3	Repetition identical to 2nd & 3rd repetitions but different from child's baseline production and from one other previous repetition (i.e. the 1st repetition).
5th Repetition	[ˈdəˈkəˈnə]	4	Repetition different from child's baseline production and two or more other previous repetitions (i.e. 1st, 2nd, 3rd & 4th repetitions).
Rating recorded for target		4	

Table 3.7iii Consistency strength scoring example:

For the target: PARTY, the child's baseline production is: [ˈpɑʔi]. For the five repetitions the child produces:

Child's baseline	[ˈpɑʔi]	Rating	Definition of rating
1st Repetition	[ˈpɑki]	2	Repetition different from child's baseline production.
2nd Repetition	[ˈpɑki]	2	Repetition identical to 1st repetition but different from child's baseline production.
3rd Repetition	[ˈpɑki]	2	Repetition identical to 1st and 2nd repetitions but different from child's baseline production.
4th Repetition	[ˈpɑʔi]	1	Repetition identical to child's baseline production.
5th Repetition	[ˈpɑʔi]	1	Repetition identical to child's baseline production.
Rating recorded for target		2	

3.7.1.6 DDK Rate

Audio recorded rates, in seconds / milliseconds, of each child repeating the targets (RWs, NWs, SSs) five times at speed were calculated using Praat (Boersma & Weenink, 2001). Using a spectrogram, the time between the start and end of an utterance was measured (see Appendix 3.11 for a scoring sheet example). Both accurate and inaccurate repetitions were accepted in the rate measure provided the correct number of syllables was produced. Short pauses, hesitations, slips and stumbles within the run of repetitions were allowed and included within the rate measurement. However, a pause of longer than 0.25 seconds duration was deemed to indicate the child had stopped. This sometimes occurred after three repetitions, but more commonly after four repetitions. Since a number of the clinical children, in particular, stopped before the run of five repetitions was complete on one or more items, it was decided that the best way to measure DDK rate in this study was per syllable, in seconds /milliseconds. Therefore, for each target, the following information was recorded: (a) the number of repetitions produced, (b) the time taken in seconds / milliseconds to produce those repetitions, (c) the time taken in seconds / milliseconds to produce each individual repetition and (d) the time taken in seconds /milliseconds to produce each individual syllable.

3.7.2 Scoring of the Mispronunciation Detection Task

The number of correct first responses in each of the four blocks of 15 items were added together to provide a score out of 60. The scores were calculated objectively by a computer, using the SIPc software (Vance et al., 2009), and converted to percentage scores as a few of the children were unable to complete all the blocks.

In addition to these quantitative measures, qualitative measures were also made by coding the error types as follows:

- Perseveration of a consonant e.g. PAT-A-CAKE produced as ['pækəkeɪk]
- Transposition of two consonants e.g. TELEPHONE produced as ['tɛfələʊn]
- A consonant feature change e.g. PARTY produced ['bɑtɪ]
- A vowel change e.g. PAT-A-CAKE produced as ['pɒtəkeɪk]
- Rejection of a correct item e.g. CARDIGAN said correctly, but the child chooses the boy who 'gets words a little bit wrong'

3.7.3 Scoring of the Oro-motor Assessment

The Isolated Movements and Sequenced Movements subtests from the Oro-motor Assessment of the DEAP (Dodd et al., 2002) were scored by the author, by viewing the video recordings. Following the test manual instructions (p.20-21) and the scoring criteria on the record sheet, the child's second attempt was scored, unless the child performed the action only once, in which case, the first attempt was scored. Standard scores and percentile ranks were derived from the raw scores.

In addition to the general scoring criteria, specific scoring advice was created to help score the tasks involving tongue elevation (one in Isolated Movements and one in Sequenced Movements). Based on the advice in Ozanne (1992), tongue elevation was considered to require two movements within the tongue i.e. protrusion and elevation of the tongue tip. The following scoring criteria were used:

Table 3.8 Scoring criteria adopted for the tasks involving tongue elevation

Score 3	Accurate performance immediately follows verbal command. This score was selected if tongue elevation was produced immediately following the verbal instruction and if there was evidence of both tongue protrusion and elevation of the tongue tip.
Score 2	Accurate performance preceded by protracted pauses during which unsuccessful movements may be present. This score was selected if tongue elevation (with both tongue protrusion and elevation of the tongue tip) was achieved but only after protracted pauses during which unsuccessful movements may be present.
Score 1	Overall pattern of movement acceptable, but defective in terms of amplitude, accuracy, force and /or speed. This score was selected if elevation was achieved but only by the tongue moving as a mass and through jaw support.
Score 0	An important part of the gesture is lacking; incorrect or non-targeted oral gestures; speech sound is produced; no oral movement. This score was selected if the tongue was protruded, with/without jaw support, but there was no evidence of tongue tip elevation.

3.7.4. Scoring of the Single sound imitation tasks

Each consonant and vowel sound produced was judged to be correct or incorrect by the author, an experienced speech and language therapist. A binary scoring method was adopted: 1 point was given for a correct production and 0 point for an incorrect production. If the children had more than one attempt, their best attempt was scored (in line with the guidance in p.18 of DEAP manual, which allows the child to have 3 opportunities to correctly imitate a single sound). The number of vowels produced correctly /18 was recorded. Scores were also converted to percentage scores.

Although all twenty-four consonants were sampled, consonant scores for individual children were calculated with reference to age norms in Appendix A of the DEAP manual (see table 3.8) and on its Summary score sheet (Dodd et al., 2002). Any consonants expected to be accurate in an age group but produced as an error were recorded for each child. Since the number of consonants expected at a given age varied, scores were converted to percentage scores.

Table 3.8 Age norms for consonant inventories between 4;0 and 7;0 years (based on DEAP manual, Appendix A, Dodd et al., 2002)

AGE	CONSONANTS	VOWELS
4; 0 – 4; 11	Score /20; all except ʃ θ ð r	All
5; 0 – 5; 11	Score /21; all except θ ð r	All
6; 6 – 6; 11	Score /22; all except θ ð	All
7;0 & above	All	All

3.7.5 Consonant errors affecting DDK segments

The number of DDK target consonants that the child was unable to articulate correctly was calculated. A segment distribution is produced in Appendix 3.5. Errors in articulating any of the following were recorded: /p/, /b/, /t/, /d/, /k/, /g/, /m/, /n/, /l/, /f/.

3.7.6 Scoring of the Phonology Assessment

Each child's Percentage Consonants Correct (PCC) on the Phonology Assessment was scored by the author, according to the DEAP manual instructions. Standard scores and percentile ranks were derived from the PCC raw scores. In addition, error patterns (phonological simplification processes) were identified following the advice in the DEAP manual (p.23) i.e. to count as an error pattern, five examples need to be identified across the 50 words produced, except for weak syllable deletion, where only two examples are required.

3.7.7 Scoring of the Inconsistency Assessment

This task was scored by the author according to the instructions in the DEAP manual (p. 25). Each item was scored 0 if the responses were the same in all three trials or given 1 point if any response was different within the three trials (see table 3.9 for examples).

Table 3.9 Scoring examples from the DEAP Inconsistency Assessment (Dodd et al., 2002).

Target	Trial 1	Trial 2	Trial 3	Score
LADYBIRD	[lɛdɪbɜd]	[lɛdɪbɜd]	[nɛdɪbɜd]	1 point
THANK YOU	[daʔdu]	[daʔdu]	[daʔdu]	0 point

This procedure was followed for each of the 25 items and a total score calculated**.** If the total score reached 10/25 or more, the record form was rechecked to see whether any of the differences across the three trials could be accounted for by variations between a correct production and a developmentally age appropriate error. If this was the case, these variations were removed and the inconsistency score re-calculated, in accordance with the manual instructions. Following this adjustment, any child who had a final score of 10/25 (40%) or more, was considered to have inconsistent speech production.

3.7.8 Scoring of connected speech rate

Connected utterances produced in response to the DEAP ‘funny’ pictures at the end of the Phonology subtest and the LDA ‘what’s wrong?’ pictures were transcribed orthographically from the audio and video recordings. Six utterances were selected (usually 3 from the DEAP picture description task and 3 from the LDA picture description task). The aim was to select utterances of varying length, but the minimum length of any utterance was three words. They were scored for rate of production using Praat (Boersma & Weenink, 2001). The number of syllables spoken, the duration of each utterance, and the duration per syllable in seconds /milliseconds were recorded. A mean rate of production per syllable, based on the six utterances, was recorded for each child. As in scoring DDK rate above, short pauses (but not longer than 0.25 ms), hesitations, slips and stumbles were allowed and included within the rate score.

3.8 Analyses

3.8.1 Statistical analyses

Data were analysed using IBM ® SPSS Version 21. The data did not meet the criteria to utilise parametric statistical tests of significance i.e. there was insufficient homogeneity of variance across conditions and groups and the clinical data in particular did not show normality of distribution. Therefore, non-parametric tests of significance were utilised:

- Mann-Whitney U tests to investigate between-group differences in performance of the clinical children and the age-matched typically-developing children.
- Wilcoxon’s matched pairs signed ranks tests (when two conditions) and Friedman’s rank tests (when more than two conditions) to examine between-condition differences within a group (clinical or typically-developing children).

Data on DDK Accuracy, DDK Consistency and DDK Rate was collected and examined as follows:

DDK Accuracy

Each child’s accuracy on single repetitions and on five repetitions was scored using two methods : (i) binary scoring (described in 3.7.1.1 and 3.7.1.2) and (ii) PCC scoring (described in 3.7.1.3). For each scoring method, the mean scores for the clinical children as a group were calculated for (a) stimulus condition (RW; NW; SS and totals across the conditions) and (b) stimulus length (2 and 3 syllables). These mean scores were then compared to the mean scores of the typical group in between-group analyses.

The mean accuracy scores obtained by each individual clinical child on single repetitions and five repetitions were also compared to the overall mean accuracy scores of the typical group, by (a) stimulus condition and (b) stimulus length.

DDK Consistency

Each child's consistency on DDK tasks was scored using two methods (i) binary scoring (described in 3.7.1.4) and (ii) consistency strength rating (described in 3.7.1.5).

For binary scoring, the mean scores for the clinical children as a group were calculated for (a) stimulus condition (RW; NW; SS and totals across the conditions) and (b) stimulus length (2 and 3 syllables). These mean scores were then compared to the mean scores of the typical group in between-group analyses.

The mean consistency scores obtained by each individual clinical child on five repetitions were also compared to the overall mean consistency scores of the typical group, by (a) stimulus condition and (b) stimulus length.

For consistency strength rating scoring, the total scores for the clinical children as a group which reached ratings 0, 1, 2, 3, 4 across the conditions (RWs; NWs; SS) were compared to the total scores from the typical children in between-group analyses.

DDK Rate

Each child's rate in seconds / milliseconds per syllable for each run of five repetitions was recorded using the method described in 3.7.1.6. The mean rates for the clinical children as a group were calculated for (a) stimulus condition (RW; NW; SS and mean rates across the conditions) and (b) stimulus length (2 and 3 syllables). These mean rates were then compared to the mean rates of the typical group in between-group analyses.

The mean rates obtained by each individual clinical child were also compared to the overall mean rates of the typical group, by (a) stimulus condition and (b) stimulus length.

In addition, the number of repetitions produced (out of a total of 5) on each target by each individual child was recorded. The mean number of repetitions, for the clinical children as a group, were calculated by syllable length in each condition and as an overall mean for each syllable length across the conditions. The overall mean number of repetitions for each syllable length were then compared to the overall mean number of repetitions of the typical group in between-group analyses.

DDK Accuracy in relation to DDK Consistency

The group mean totals on binary scoring (n=/24) for DDK accuracy and DDK consistency (n=/24) of the clinical children were compared to identify differences in performance. The relationship between the clinical children's DDK accuracy and DDK consistency scores was also examined using Spearman's rho correlational analyses. The group mean totals of the typical children on DDK accuracy and DDK consistency were examined in the same way.

The mean totals (n=/24) on DDK accuracy and DDK consistency of the clinical and typical children as groups were then compared. Furthermore, the mean totals of each individual clinical child on DDK accuracy and DDK consistency was compared to the typical group's overall mean total scores.

DDK Accuracy in relation to DDK Rate

The group mean totals on binary scoring (n=/24) for DDK accuracy of the clinical children were compared to their mean overall DDK rates (seconds/syllable) to identify differences in performance. The relationship between the clinical children's DDK accuracy and DDK rate scores was also examined using Spearman's rho correlational analyses. The same procedure was followed for the typical group.

The mean totals (n=/24) on DDK accuracy and the mean DDK rates (in seconds per syllable) of the clinical and typical children as groups were then compared. Furthermore, the mean total accuracy scores (n=/24) and the DDK mean rate of each individual clinical child were compared to the typical group's overall mean scores.

DDK measures and other speech processing measures

Spearman's rho correlational analyses were used to investigate the relationship between the clinical children's DDK performance (separately for accuracy, consistency, rate) and their performance on other variables: accuracy of lexical representations, oral motor skills, accuracy of single consonant sound imitation, accuracy of single word naming, consistency of single word naming and connected speech rate.

3.8.2 Sample size and statistical power consideration

The sample size (n=40) was limited by the availability of suitable participants. However, such a sample was deemed sufficient to test hypotheses about moderate (d= 0.50) between group differences and moderate correlations. A sample size of 40 was also sufficient to detect a true correlation of .41 with 80% probability. However, once participants were sub-grouped (e.g. according to age or by DDK profile), only hypotheses about strong effects could be tested with sufficient statistical power.

3.9 Inter-tester reliability

Fifteen (37.5%) of the forty clinical children's DDK data (single and five repetitions) and fifteen (37.5%) of the typical children's DDK data (single and five repetitions) were independently transcribed by a second, phonetically trained marker, and scored by both binary and PCC methods. In addition, a phonetically trained second marker independently transcribed and scored ten of the forty (25%) children's DEAP Phonology Assessments for PCC and phonological error patterns and four of the sixteen (25%) children's DEAP Inconsistency Assessments. Ten of the forty (25%) children's DEAP Oro-motor Assessments on Isolated Movements (IM) and Sequenced Movements (SM) were scored independently by an experienced speech and language therapist. All data marked by a second marker was selected at random from the whole data set.

3.9.1 Inter-tester reliability on single repetitions

Correlational analyses, using Spearman's rho, were carried out to investigate the inter-tester ratings between the first and second marker for single repetitions of DDK targets (see table 3.10). For the clinical children, highly significant ($p<0.01$) correlations were found between the two markers on the mean accuracy scores (binary and PCC) of single repetitions in each of the stimulus conditions (RW, NW, SS). For the typical children, significant ($p<0.05$) or highly significant ($p<0.01$) correlations were found between the two markers on the mean accuracy scores (binary) in all stimulus conditions. This was also the case for mean PCC scores in the NW and SS conditions, but not in the RW condition. Examination of the RW PCC raw data showed that the two markers disagreed on only six consonants in the total set of three hundred consonants.

Table 3.10. Inter-tester reliability for accuracy (binary and PCC) of single repetitions - correlation coefficients and significance levels for each stimulus condition.

	Real words	Non-words	Syllable sequences
Clinical children binary	.815	.898	.889
	p<0.01	p<0.01	p<0.01
Clinical children PCC	.819	.895	.800
	p<0.01	p<0.01	p<0.01
Typical children binary	.649	.675	.637
	p<0.01	p<0.01	p<0.05
Typical children PCC	.393	.694	.584
	p=.147	p<0.01	p<0.05

Key: PCC=Percentage Consonants Correct

3.9.2 Inter-tester reliability on five repetitions

Correlational analyses, using Spearman's rho, were carried out to investigate the inter-tester ratings between the first and second marker for five repetitions of DDK stimuli (see table 3.11). Highly significant ($p<0.01$) correlations were found between the two markers on the clinical children's mean accuracy scores (binary and PCC) of five repetitions in each of the stimulus conditions (RW, NW, SS). For the typical children, significant ($p<0.05$) or highly significant ($p<0.01$) correlations were found between the two markers on the mean accuracy scores (binary and PCC) in all stimulus conditions.

Table 3.11 Inter-tester reliability for accuracy (binary and PCC) of five repetitions- correlation coefficients and significance levels for each stimulus condition.

	Real words	Non-words	Syllable sequences
Clinical children binary	.945	.915	.940
	p<0.01	p<0.01	p<0.01
Clinical children PCC	.904	.975	.922
	p<0.01	p<0.01	p<0.01
Typical children binary	.879	.599	.732
	p<0.01	p<0.05	p<0.01
Typical children PCC	.624	.749	.783
	p<0.05	p<0.01	p<0.01

3.9.3 Inter-tester reliability on DEAP Phonology Assessment, DEAP Inconsistency Assessment and DEAP Oromotor Assessment (IM & SM)

Correlational analysis, using Spearman's rho, showed a strong positive relationship between the scores produced by the two markers on all of these assessments. For the PCC scores the correlation coefficient was.951, $p<0.01$; for the Inconsistency scores the correlation coefficient was .894, $p<0.05$; for the Isolated Movements the correlation coefficient was .850, $p<0.01$ and for the Sequenced Movements the correlation coefficient was .914, $p<0.01$.

The study results will be presented in Chapters Four, Five, Six, Seven and Eight.

Chapter Four

Results I: DDK Accuracy

4.1 Research questions

The following research questions will be considered in this chapter:

(a) How accurate are a group of children with speech difficulties, aged 4-7 years, on (a) single repetitions and (b) five repetitions in DDK tasks?

(b) How does their accuracy performance on (a) single repetitions and (b) five repetitions in DDK tasks compare to that of age-matched typically-developing children?

4.2 Data

Each child was asked to repeat the target once after the tester, before producing a run of five repetitions, in order to establish a baseline against which the subsequent five repetitions were compared. Each single repetition and each set of five repetitions of the individual targets were scored for accuracy using the two different scoring methods presented in Chapter Three: (1) Binary scoring (1 point for correct and 0 point for incorrect, based on the set criteria) and (2) Percentage Consonants Correct (PCC).

The clinical and typical children's individual scores on each target were recorded. The set of individual scores from the clinical children were combined and compared to the set of combined scores from the typical children for the between-group comparisons. Data were analysed by (a) stimulus condition (Real Word - RW; Non-word - NW; Syllable Sequences - SS) and (b) stimulus length (2 vs. 3 syllables). There was missing data for one clinical child (43) who did not co-operate for the SS condition and for one typical child (23) who did not complete the NW and SS conditions and therefore total scores (binary) and mean scores (PCC) for these children could not be calculated.

4.3 Stimulus Condition

4.3.1 Clinical children: Accuracy of single repetitions in RW, NW and SS conditions

Individual children's scores obtained from binary and PCC scoring are listed in Appendices 4.1 and 4.2**.** The results for the clinical group from the binary scoring method are presented in table 4.1 and from the PCC method in table 4.2.

Table 4.1 Clinical children (n=40): Single repetition accuracy scores (binary /8) by stimulus condition and combined totals (n/24).

Accuracy X 1 Binary	RW /8	NW /8	SS /8	Totals /24
Mean	5.18	5.23	5.41	16.03
s.d.	2.47	2.35	2.29	6.59
Median	5.00	6.00	6.00	16.00
Minimum	.00	.00	.00	2.00
Maximum	8.00	8.00	8.00	24.00

Key: Accuracy x 1= Accuracy of single repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences; s.d. =standard deviation.

Table 4.2 Clinical children (n=40): Single repetition accuracy scores (PCC) by stimulus condition and mean PCC.

Accuracy X 1 PCC	RW	NW	SS	Mean
Mean	82.13	83.73	84.74	83.91
s.d.	18.52	16.75	16.79	16.20
Median	88.00	88.00	88.00	88.00
Minimum	44.00	38.00	34.00	39.33
Maximum	100.00	100.00	100.00	100.00

Key: Accuracy x 1 =Accuracy of single repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences; s.d.=standard deviation.

There was considerable individual variation within the clinical group in each of the three stimulus conditions, on both binary and PCC scores. Friedman ranks tests showed there were no significant differences in the clinical children's group mean scores across the stimulus conditions, for either binary (p=0.600) or PCC (p=0.626) scores.

4.3.2 Typical children: Accuracy of single repetitions in RW, NW and SS conditions

Individual children's scores obtained from binary and PCC scoring are listed in Appendices 4.3 and 4.4**.** The results for the typical group from the binary scoring method are presented in table 4.3 and from the PCC method in table 4.4.

Table 4.3 Typical children (n=40): Single repetition accuracy scores (binary /8) by stimulus condition and combined totals (n/24).

Accuracy X 1 Binary	RW /8	NW /8	SS /8	Totals /24
Mean	7.80	7.77	7.77	23.33
s.d.	.56	.54	.67	1.47
Median	8.00	8.00	8.00	24.00
Minimum	6.00	6.00	5.00	17.00
Maximum	8.00	8.00	8.00	24.00

Key: Accuracy x 1 =Accuracy of single repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences;; s.d. =standard deviation.

Table 4.4 Typical group (n=40): Single repetition accuracy scores (PCC) by stimulus condition and mean PCC.

Accuracy X 1 PCC	RW	NW	SS	Mean
Mean	99.10	98.87	98.87	98.97
s.d.	2.64	3.17	4.02	2.49
Median	100.00	100.00	100.00	100.00
Minimum	88.00	84.00	78.00	87.33
Maximum	100.00	100.00	100.00	100.00

Key: Accuracy x 1 =Accuracy of single repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences; s.d.= standard deviation.

The median scores for the typical group were at ceiling on both binary and PCC scores, despite some minor individual variation in each stimulus condition. Friedman ranks tests showed there were no significant differences in the typical children's mean scores across stimulus conditions for either binary (p=0.905) or PCC (p=0.741) scoring.

4.3.3 Comparison of clinical and typical children as groups on single repetition accuracy across the stimulus conditions

The mean scores of the clinical group were significantly lower (p<0.001) than the typical group for both binary and PCC scoring (see table 4.5).

Table 4.5 Comparison of clinical and typical groups (n=40) on single repetition accuracy scores (binary and PCC) by stimulus condition.

	RWs	NWs	SSs	Mean total /24	Mean PCC
Binary	z=-5.655 p<0.001	z=-5.924 p<0.001	z=-5.742 p<0.001	z=-6.214 p<0.001	
PCC	z=-5.444 p<0.001	z=-5.779 p<0.001	z=-5.516 p<0.001		z=-5.825 p<0.001

Key: RWs=Real Words, NWs=Non-Words, SSs=Syllable Sequences, PCC=Percentage Consonants Correct. Z= significant at +/-1.65.

There was a wider range of accuracy performance in the clinical group, compared to the typical group (see figures 4.1 and 4.2), most of whom were at or near ceiling. The exceptions were seven typical children who scored below the rest of the group. Examination of the individual scores shows that most of these outliers did not score particularly poorly. However, since all the rest of the typical group performed so highly, even a small number of errors caused the children to become outliers to the overall group performance.

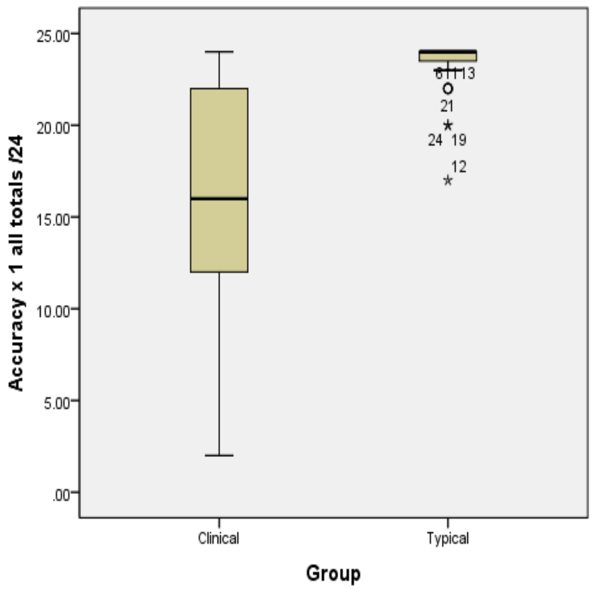


Figure 4.1 Single repetition mean accuracy totals (binary /24) across all conditions: comparison of clinical and typical groups.

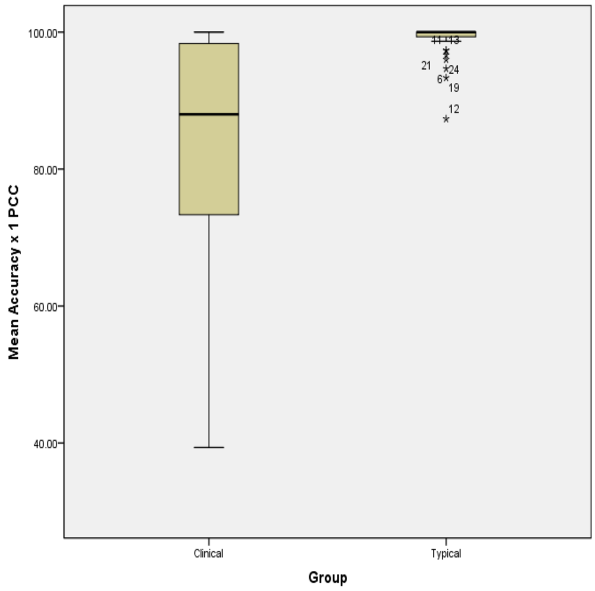


Figure 4.2 Single repetition mean accuracy scores (PCC) across all conditions: comparison of clinical and typical groups.

4.3.4 Individual clinical children's scores compared to the typical children's group scores on single repetition accuracy, across the stimulus conditions

Each individual clinical child's total accuracy scores (binary /24) and mean accuracy scores (PCC) were compared to the typical children's group scores and z scores were calculated. A full list of these results is given in Appendix 4.5 and is summarised in table 4.6. The majority of the clinical children who scored significantly differently from the typical children (total of 26 on binary scoring and total of 25 on PCC) did so at a highly significant level ($p<0.001$): 24/26 children on binary and 23/25 on PCC (see Appendix 4.5 for details).

Table 4.6 Single repetition accuracy scores of individual clinical children (n=40) compared to typical group mean scores.

	Binary	PCC
Missing	1 (2.5%)	1 (2.5%)
Not significant	13 (32.5%)	14 (35%)
Significant (at any level of significance)	26 (65%)	25 (62.5%)

Key: PCC=Percentage Consonants Correct.

Over 62% (N=25 or more) of the clinical children scored significantly differently to the typical group mean scores on both scoring methods, and mainly at a highly significant level. However, there was individual variation within the clinical group and around one third of the children scored no differently to the typical group. This variation may reflect the broad inclusion criteria for this study and the known heterogeneity of children with speech difficulties. It is also likely to reflect the specific nature of the individual children's presenting difficulties with consonant sounds, as only a limited range of consonants were sampled in the DDK targets.

Examination of the clinical children's individual scores (see Appendix 4.5) showed that the majority of children scored similarly, across the stimulus conditions. However, a few children performed considerably better in one or other condition e.g. CS5 who performed better on RWs than on NWs and SSs on both scoring methods, but particularly on PCC scoring; and LS5 who performed more poorly on RWs than on NWs or SSs on both scoring methods. Such differences may in part be explained by test factors such as, the order in which these particular children received the tasks, attention and/or tiredness, but may also indicate some possible differences in the level of breakdown underlying the individual children's speech difficulties.

4.3.5 Summary of the results for single repetition accuracy, by stimulus condition:

- As a group, the clinical children scored significantly more poorly than the group of typical children, most of whom were at or near ceiling
- There was no difference in mean accuracy performance across conditions (i.e. RW, NW, SS) in either the clinical or typical groups, using either scoring method.
- A small number of clinical children performed significantly better in one or other conditions.
- There was considerable individual variation within the clinical group and around a third of the children scored no differently to the typical children on these speech accuracy measures.

4.3.6 Clinical children: Accuracy of five repetitions in RW, NW and SS conditions

Individual children's scores obtained from binary and PCC scoring are listed in Appendices 4.6 and 4.7**.** The results for the clinical group from the binary scoring method are presented in table 4.7 and from the PCC method in table 4.8.

Table 4.7 Clinical children (n=40): Five repetitions accuracy scores (binary /8) by stimulus condition and combined totals (n/24).

Accuracy X 5 Binary	RW /8	NW /8	SS /8	Total /24
Mean	4.00	3.45	3.49	11.08
s.d.	2.59	2.47	2.10	6.50
Median	3.50	3.00	3.00	11.00
Minimum	.00	.00	.00	1.00
Maximum	8.00	8.00	7.00	23.00

Key: Accuracy x 5 = Accuracy of five repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences; s.d.=standard deviation.

Table 4.8 Clinical children (n=40): Five repetitions accuracy scores (PCC) by stimulus condition and mean PCC.

Accuracy X 5 PCC	RW	NW	SS	Mean
Mean	79.68	79.50	78.90	79.79
s.d.	19.09	18.68	18.09	17.74
Median	83.50	79.00	83.00	85.50
Minimum	44.00	32.00	30.00	38.67
Maximum	100.00	100.00	100.00	99.67

Key: Accuracy x 5 = Accuracy of five repetitions; RW=Real word; NW=Non-word; SS=Syllable sequences s.d.=standard deviation.

For binary scoring, there was considerable individual variation within the clinical group, in each of the three stimulus conditions. Wilcoxon matched pairs signed rank tests showed that the children's mean score on RW targets was significantly higher than on NWs ($z=-2.001$, $p<0.05$), and the effect size was medium ($r=0.32$). However, there was no significant difference between their mean scores on RWs and SSs ($z=-1.825$, $p=.068$) or between their mean scores on NWs and SSs ($z=0.157$, $p=.875$). For PCC scoring, there was also considerable individual variation in each condition. However, a Friedman ranks test showed there were no significant differences ($p=.425$) between the clinical group's mean accuracy scores (PCC) on RWs, NWs or SSs.

4.3.7 Typical children: Accuracy of five repetitions in RW, NW and SS conditions

Individual children's scores obtained from binary and PCC scoring are listed in Appendices 4.8 and 4.9**.** The results for the typical group from the binary scoring method are presented in table 4.9 and from the PCC method in table 4.10.

Table 4.9 Typical children (n=40): Five repetitions accuracy scores (binary /8) by stimulus condition and combined totals (n/24).

Accuracy X 5 Binary	RW /8	NW /8	SS /8	Total /24
Mean	6.83	6.13	6.21	19.13
s.d.	1.22	1.63	1.00	2.75
Median	7.00	6.00	6.00	19.00
Minimum	4.00	2.00	4.00	13.00
Maximum	8.00	8.00	8.00	23.00

Key: Accuracy x 5 = Accuracy of five repetitions; RW=Real word, NW=Non-word, SS=Syllable sequences; s.d.=standard deviation.

Table 4.10 Typical group (n=40): Five repetitions accuracy scores (PCC) by stimulus condition and mean PCC total.

Accuracy X 5 PCC	RW	NW	SS	Mean
Mean	98.63	96.82	97.03	97.48
s.d.	2.59	5.51	3.93	2.87
Median	100.00	99.00	99.00	98.67
Minimum	88.00	81.00	84.00	88.47
Maximum	100.00	100.00	100.00	100.00

Key: RW=Real word, NW=Non-word, SS=Syllable sequences. Acc x 5 = Accuracy of five repetitions; s.d.=standard deviation.

For binary scoring, there was some individual variation in each condition. Wilcoxon matched pairs signed rank tests showed that the typical children's mean accuracy score on RWs was significantly higher than on NWs ($z=-2.041$, $p<0.05$) and on SSs ($z=-2.556$, $p<0.05$). However, there was no significant difference between their mean accuracy scores on NWs and SSs ($z=-0.189$, $p=.850$). For PCC scoring, the typical children's mean and median accuracy scores were at or near ceiling in each of the three stimulus conditions. Wilcoxon signed ranks tests showed that the typical children were significantly more accurate when producing five repetitions of RWs than when producing five repetitions of NWs ($z=-2.024$, $p<0.05$) and SSs ($z=-2.623$, $p<0.01$). However, there was no significant difference between their accuracy of five repetitions of NWs and SSs ($z=-0.702$. $p=0.483$).

4.3.8 Comparison of clinical and typical children as groups on five repetitions accuracy across the stimulus conditions

The mean scores of the clinical group were significantly lower ($p<0.001$) than the typical group in each condition and for both mean totals (binary) and mean PCC scores (see table 4.11).

Table 4.11 Comparison of clinical and typical groups on five repetitions accuracy scores (binary and PCC) by stimulus condition.

	RWs	NWs	SSs	Mean total /24	Mean PCC
Binary	$z= -4.832$ $p<0.001$	$z=-4.671$ $p<0.001$	$z=-5.572$ $p<0.001$	$z=-5.272$ $p<0.001$	
PCC	$z=-5.216$ $p<0.001$	$z=-4.919$ $p<0.001$	$z=-5.591$ $p<0.001$		$z=-5.460$ $p<0.001$

Key: RWs=real words; NWs=non-words; SSs =syllable sequences; PCC=Percentage consonants correct.

For binary scoring, there was a wider range of accuracy performance in the clinical group, compared to the typical group (see figure 4.3), and the median scores of the typical group were higher than the clinical group. For PCC scoring, the clinical children showed a wider range of accuracy performance than the typical children, most of whom were at or near ceiling (see figure 4.4). The exceptions were two typical children (19 and 12) who scored below the rest of the group. Examination of the individual scores shows that these outliers did not score particularly poorly. However, since all the rest of the typical group performed so well, even a small number of errors caused the children to become outliers to the overall group performance.

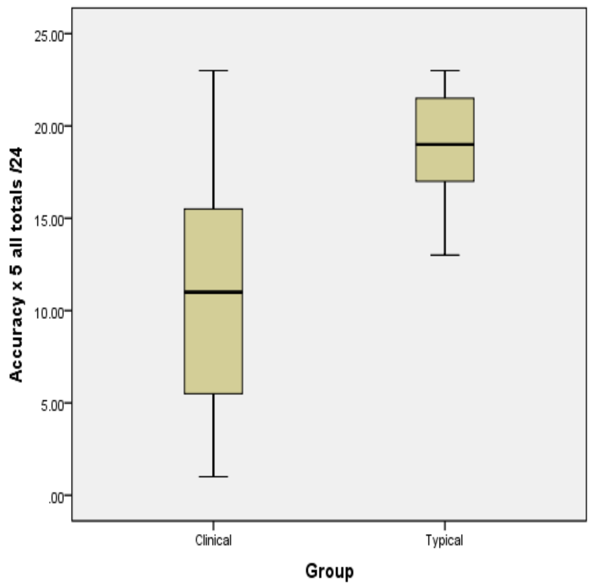


Figure 4.3 Five repetitions mean accuracy totals (binary /24) across all conditions: comparison of clinical and typical groups.

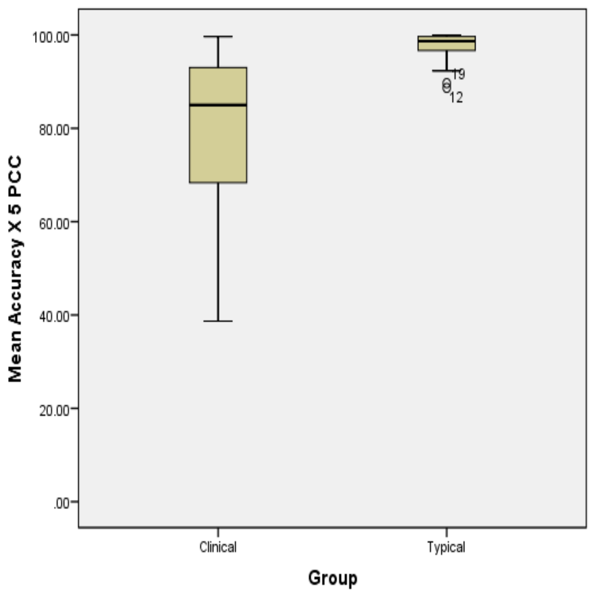


Figure 4.4 Five repetitions mean accuracy scores (PCC) across all conditions: comparison of clinical and typical groups.

4.3.9. Individual clinical children's scores compared to the typical children's group scores on five repetitions accuracy across the stimulus conditions

The total accuracy scores (binary /24) and the mean accuracy scores (PCC) of each individual clinical child were compared to the typical group's scores and z scores were calculated. A full list of these results is given in Appendix 4.10 and is summarised in table 4.12.

Table 4.12 Five repetitions accuracy scores of individual clinical children (n=40) compared to typical group mean scores.

	Binary	PCC
Missing	1 (2.5%)	1 (2.5%)
Not significant	11 (27.5%)	10 (25%)
Significant (at any level of significance)	28 (70%)	29 (72.5%)

Key: PCC=Percentage consonants correct.

The results were similar for the two scoring methods. Around one quarter of the clinical children performed similarly to the typical children, while the remaining children scored significantly differently. The majority of the clinical children who scored significantly differently to the typical children (total of 28 on binary scoring and total of 29 on PCC scoring) did so at a highly significant level ($p<0.01$ or $p<0.001$): 23/28 children on binary and 26/29 on PCC (see Appendix 4.10 for details).

4.3.10 Summary of the results for five repetitions accuracy, by stimulus condition:

- There were some differences in scores obtained from the two scoring methods (binary and PCC). However, the results overall were similar.
- As a group, the clinical children scored significantly more poorly than the group of typical children, most of whom were at or near ceiling.
- As a trend, both groups produced five repetitions of RWs more accurately than NWs or SSs, but this only reached significance for the binary scoring method.
- There was considerable individual variation within the clinical group and around one quarter of the children scored no differently to the typical children on these speech accuracy measures.

4.3.11 Comparison between the summary results for single and five repetitions, by stimulus condition:

- As groups, the clinical children scored significantly more poorly than the typical children on accuracy of both single and five repetitions.
- On single repetition, one third of the individual clinical children scored no differently to the typical children, whereas on five repetitions only one quarter of the clinical children scored no differently to the typical children. This indicates that the clinical

children found it more difficult to maintain accuracy on five repetitions of a target than on a single repetition.

- On single repetition accuracy, the clinical children scored similarly whether it was a RW, NW or SS target. On accuracy of five repetitions, there was an advantage in favour of RW repetition, although this only reached significance for the binary scoring method.

4.4 Stimulus Length

4.4.1 Clinical children: Accuracy of single repetitions on 2 and 3 syllable targets

Individual scores from binary and PCC scoring are listed in Appendices 4.11 and 4.12. The results for the clinical group from the binary scoring method are presented in table 4.13 and from the PCC method in table 4.14.

Table 4.13 Clinical children (n=40): Single repetition accuracy scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and total mean scores.

Accuracy X 1 Binary /4	RW2	RW3	NW 2	NW 3	SS2	SS 3	Means	
							2	3
Mean	2.98	2.15	3.00	2.23	3.18	2.23	3.09	2.24
s.d.	1.29	1.51	1.13	1.48	1.14	1.35	1.06	1.30
Median	4.00	2.00	3.00	2.50	4.00	2.00	3.67	2.33
Min	.00	.00	.00	.00	.00	.00	.67	.00
Max	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Key: Accuracy x 1= Accuracy of single repetitions; RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

Table 4.14 Clinical children (n=40): Single repetition accuracy scores (PCC) by stimulus length (2 vs. 3 syllables) in each stimulus condition and mean totals.

Accuracy X 1 PCC	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	84.83	79.25	85.48	81.65	88.59	80.54	86.79	80.76

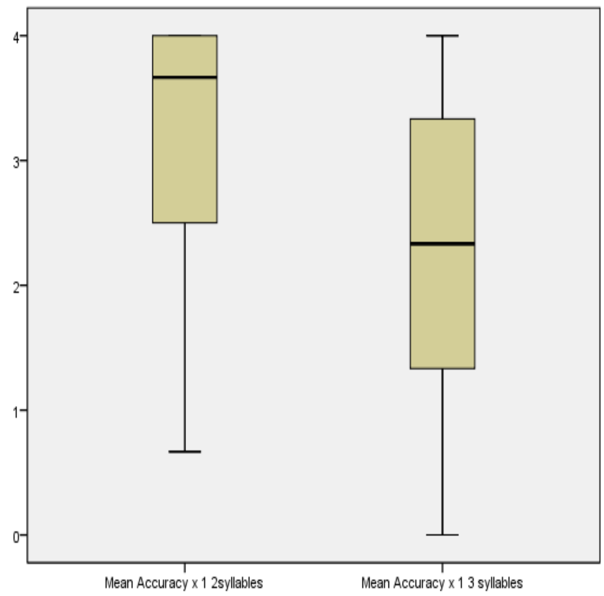
s.d.	19.81	20.76	17.55	19.72	16.73	19.24	15.91	18.57
Median	100.00	83.00	88.00	92.00	100.00	83.00	96.00	82.67
Min	38.00	25.00	38.00	25.00	38.00	22.00	50.33	24.00
Max	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Key: Accuracy x 1 =Accuracy of single repetitions; RW2=2 syllable real words, RW3=3 syllable real words, NW2=2 syllable non-words, NW3=3 syllable non-words, SS2=2 syllable, syllable sequences, SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

There was considerable individual variation in both binary and PCC scores on 2 and 3 syllable targets, in all stimulus conditions. On binary scoring, Wilcoxon matched pairs signed ranks tests showed there were highly significant differences between the clinical children's performance on 2 and 3 syllable targets in all conditions (RWs: $z=-3.411$, $p<0.01$; NWs: $z=-3.551$, $p<0.001$; SSs: $z=-4.210$, $p<0.001$) and on mean totals ($z=-4.620$, $p<0.001$) (see figure 4.5).

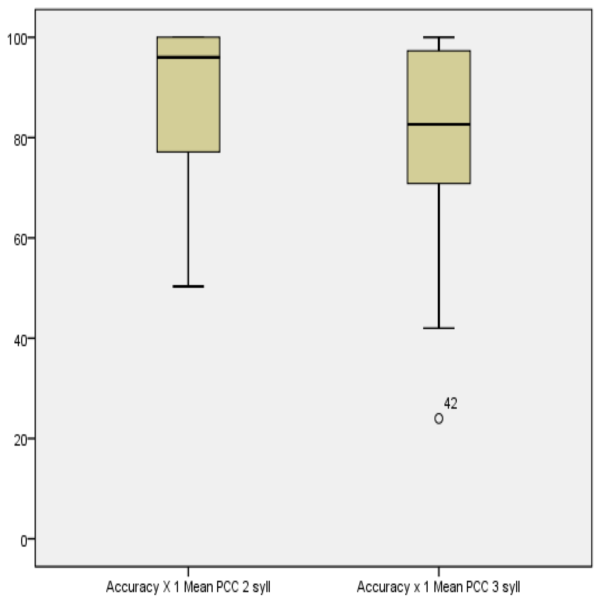
On PCC scoring, Wilcoxon signed ranks tests showed significant differences between PCC scores on 2 and 3 syllable targets for SSs ($z=-3.553$, $p<0.001$) and for mean totals ($z=-2.955$, $p<0.01$) (see figure 4.6) . In both cases, the clinical children were significantly more accurate when repeating shorter than longer DDK targets. In comparison, there were no significant differences in scores on 2 and 3 syllable targets for NWs ($z=1.339$, $p=.181$) or RWs ($z=-1.931$, $p=.053$), although the latter was approaching significance. Examination of the PCC scores shows that there were some differences in the children's performances across the conditions on the different stimulus lengths. On 2 syllable targets, the children scored best on SSs, followed by NWs and then RWs, whereas on 3 syllable targets, the children scored best on NWs, followed by SSs and then RWs. Furthermore, there was slightly more variation within the 3 syllable SSs (range 22-100) than on either RWs or NWs (range 25-100). These differences may account for the non-significant results between the children's scores on 2 vs. 3 syllables on RWs and NWs, using the PCC scoring method.

There was wide individual variation on 3 syllable targets for binary (range 0-4) and PCC (range 24-100) scoring. Child 42 (DC4) scored a mean of 0.33/4 for binary and 24 for PCC. Examination of the individual scores (Appendices 4.11 and 4.12) showed that other children scored lower on binary scoring (i.e. a mean score of 0), whereas on PCC, child 42's score of 24 was the lowest recorded and thus he presents as an outlier.



Clinical group

Figure 4.5 Clinical children: Single repetition accuracy (binary /4) - comparison of the mean totals for 2 and 3 syllable targets.



Clinical group

Figure 4.6 Clinical children: Single repetition accuracy (PCC) - comparison of the mean totals for 2 and 3 syllable targets.

4.4.2. Typical children: Accuracy of single repetitions on 2 and 3 syllable targets

Individual scores from binary and PCC scoring are listed in Appendices 4.13 and 4.14. The results for the typical group from the binary scoring method are presented in table 4.15 and from the PCC method in table 4.16.

Table 4.15 Typical children (n=40): Single repetition accuracy scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and total mean scores.

Accuracy X 1 Binary /4	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	4.00	3.80	3.95	3.82	3.95	3.82	3.97	3.81
s.d.	.00	.56	.32	.45	.22	.51	.13	.44
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Min	4.00	2.00	2.00	2.00	3.00	2.00	3.33	2.00
Max	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Key: Accuracy x 1= Accuracy of single repetitions; RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

Table 4.16 Typical children (n=40): Single repetition accuracy scores (PCC) by stimulus length in each stimulus condition and mean totals.

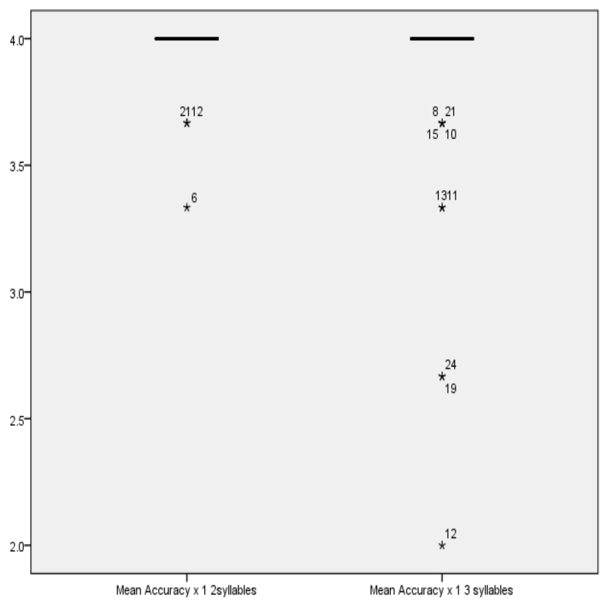
Accuracy X 1 PCC	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	100.00	98.75	99.36	98.31	99.38	98.31	99.58	98.44
s.d.	.00	4.06	4.00	4.36	2.68	6.06	1.58	4.28
Median	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Min	100.00	83.00	75.00	83.00	88.00	67.00	91.67	77.67
Max	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Key: Accuracy x 1=Accuracy of single repetitions; RW2=2 syllable real words, RW3=3 syllable real words, NW2=2 syllable non-words, NW3=3 syllable non-words, SS2=2 syllable, syllable sequences, SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

The median scores of the typical group were at ceiling for both stimulus lengths in all conditions, for both binary and PCC scores. For binary scoring, Wilcoxon signed ranks tests showed no differences between scores on 2 and 3 syllable targets in the NW and SS conditions (z=-1.318, p=0.187 and z=-1.890, p=0.059, respectively). However, in the RW condition and on combined mean totals there was a significant (p<0.05) difference (z=-2.070 & z=-2.090 respectively) since the children were more accurate on 2 syllable than 3 syllable targets. For PCC scoring, Wilcoxon signed ranks tests showed no differences between scores on 2 and 3 syllable targets in any of the three conditions: RWs (z=-1.857, p=.063), NWs (z=1.179, p=.238), SSs (z=1.461, p=.144) or for mean totals: (z=-1.785, p=.074). Thus, the typical children repeated longer 3 syllable targets as accurately as they produced shorter 2 syllable targets.

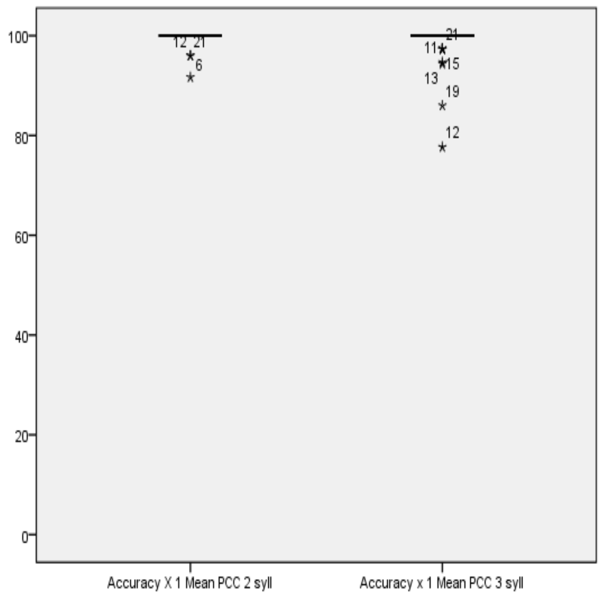
On binary scoring (see figure 4.7), the mean totals of the typical children were at ceiling for both 2 and 3 syllable targets. The main difference between the typical children's performance on the two different stimulus lengths is in the number of outliers to the overall group performance. On shorter targets (2 syllable), there were three extreme outliers, whereas on longer targets (3 syllable), there were nine.

On PCC scoring (see figure 4.8), the typical children were also at ceiling for both 2 and 3 syllable targets. As for binary scoring, the main difference in the children's performance on the two stimulus lengths was in the number of outliers to the overall group performance. For 2 syllable targets, there were three extreme outliers, whereas for 3 syllable targets, there were six. Essentially this reflects the more flexible nature of PCC scoring, whereby any consonants not elicited are removed (e.g. because the child refused to attempt the target), still allowing a maximum score to be recorded based on what the child did produce.



Typical group

Figure 4.7 Typical children: Single repetition accuracy (binary /4) - comparison of the mean totals for 2 and 3 syllable targets.



Typical group

Figure 4.8 Typical children: Single repetition accuracy (PCC) - comparison of the mean scores for 2 and 3 syllable targets.

4.4.3 Comparison of clinical and typical children's groups on single repetition accuracy on 2 and 3 syllable targets

The clinical children were significantly less accurate (binary and PCC) than the typical children ($p<0.001$) on both stimulus lengths, in each stimulus condition and for mean totals (see Table 4.17).

Table 4.17 Comparison between clinical and typical groups (n=40) on single repetition accuracy by stimulus length.

	RW2	RW3	NW2	NW3	SS2	SS3	Mean2	Mean3
Binary	z= -4.905 p<0.001	z= -5.513 p<0.001	z= -4.980 p<0.001	z= -5.560 p<0.001	z= -4.009 p<0.001	z= -5.770 p<0.001	z= -5.274 p<0.001	z= -6.100 p<0.001
PCC	z= -4.903 p<0.001	z= -5.442 p<0.001	z= -4.846 p<0.001	z= -5.120 p<0.001	z= -4.020 p<0.001	z= -5.515 p<0.001	z= -5.101 p<0.001	z= -5.579 p<0.001

Key : RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; z=significant at +/-1.65.

On 2 syllable targets, there was individual variation within the clinical group. The typical group's median scores were at ceiling, but there were three extreme outliers: children 12, 21 and 6, who scored below the rest of the group on both scoring methods (see figures 4.9 and 4.10).

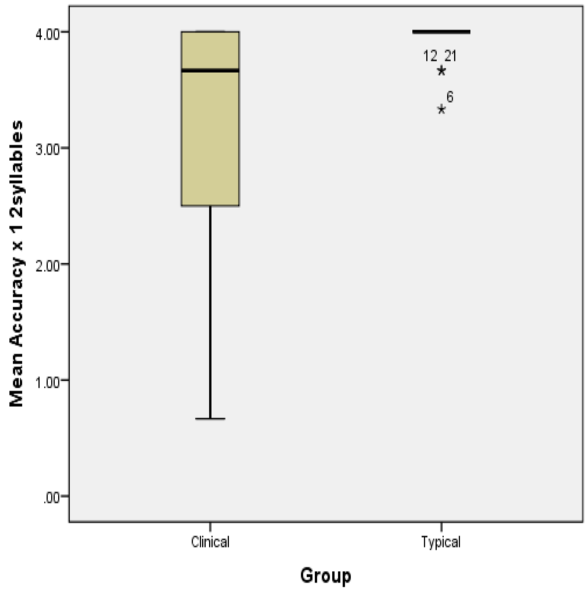


Figure 4.9 Comparison between clinical and typical groups on single repetition accuracy (binary mean scores) of 2 syllable targets.

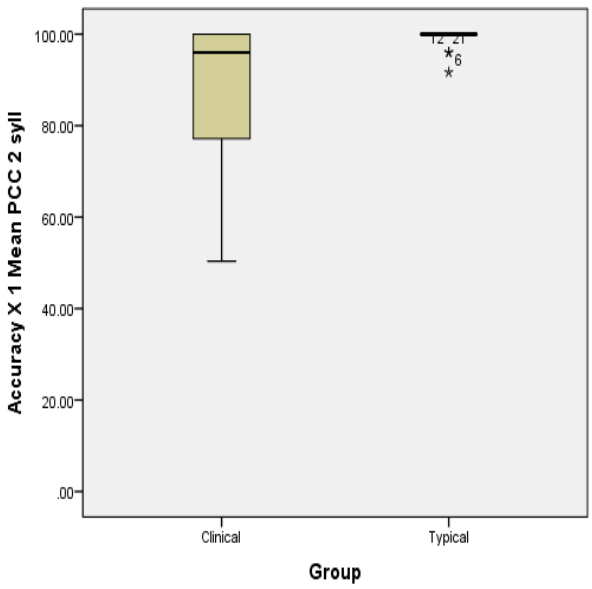


Figure 4.10 Comparison between clinical and typical groups on single repetition accuracy (PCC mean scores) of 2 syllable targets.

On 3 syllable targets, the median score of the typical group was at ceiling for both scoring methods. Within the clinical group, there was considerable individual variation. Figures 4.11 and 4.12 illustrate some differences between the two scoring methods. For the clinical children, there was more individual variation in binary than PCC scoring, with the result that one clinical child (42) emerged as an outlier on PCC but not on binary scoring. For the typical children, there were more outliers on binary (9) than on PCC (6) scoring (see comments about the two different scoring methods above for likely explanation).

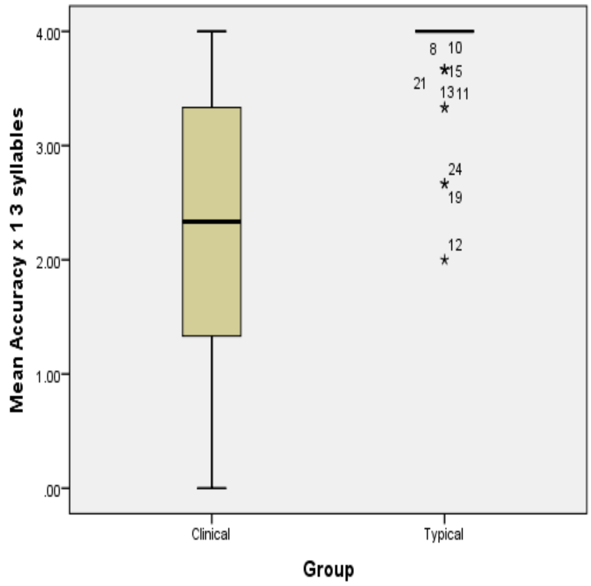


Figure 4.11 Comparison between clinical and typical groups on single repetition accuracy (binary mean scores) of 3 syllable targets.

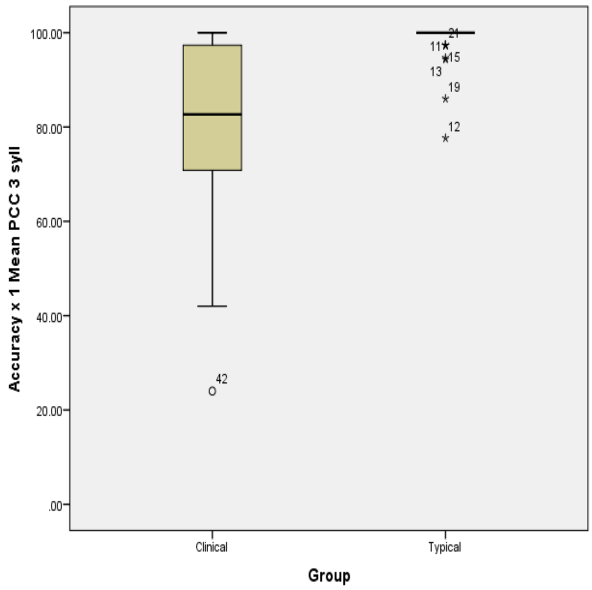


Figure 4.12 Comparison between clinical and typical groups on single repetition accuracy (PCC mean scores) of 3 syllable targets.

4.4.4 Summary of the results for single repetition accuracy by stimulus length

- There were some differences in scores obtained from the two scoring methods. However, the overall mean group results were similar.
- The median scores of the typical children were at ceiling for both 2 and 3 syllable targets.

- There was considerable individual variation within the clinical group and around a third of the children scored no differently to the typical children.
- As a group, the clinical children were significantly more accurate overall when repeating shorter (2 syllable) than longer (3 syllable) targets.

4.4.5 Clinical children: Accuracy of five repetitions of 2 and 3 syllable targets

Individual scores from binary and PCC scoring are listed in Appendices 4.17 and 4.18. The clinical group's results from the binary scoring method are presented in table 4.18 and from the PCC method in table 4.19.

Table 4.18 Clinical children (n=40): Five repetitions accuracy scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and total mean scores.

Accuracy X 5 Binary /4	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	2.65	1.35	2.13	1.35	2.41	1.08	2.43	1.28
s.d.	1.33	1.42	1.26	1.48	1.33	.98	1.11	1.16
Median	3.00	1.00	2.00	1.00	2.00	1.00	2.67	.67
Min	.00	.00	.00	.00	.00	.00	.33	.00
Max	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67

Key: Accuracy x 5= Accuracy of five repetitions; RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

Table 4.19 Clinical children (n=40): Five repetitions accuracy scores (PCC) by stimulus length (2 vs. 3 syllables) in each stimulus condition and mean totals.

Accuracy X 5 PCC	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	81.93	77.10	79.85	78.73	84.03	73.41	82.43	76.79
s.d.	21.22	19.64	20.15	19.75	18.05	20.64	18.20	18.79
Median	88.00	77.50	82.50	79.50	88.00	75.00	89.33	79.67
Min	34.00	25.00	16.00	25.00	44.00	16.00	41.00	24.67
Max	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.33

Key: Accuracy x 5 =Accuracy of five repetitions; RW2=2 syllable real words, RW3=3 syllable real words, NW2=2 syllable non-words, NW3=3 syllable non-words, SS2=2 syllable, syllable sequences, SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

Within the clinical group, there was considerable individual variation, using both scoring methods. For binary scoring, Wilcoxon matched pairs signed ranks tests showed there were highly significant differences between accuracy scores on 2 and 3 syllable targets, in all three conditions and for total mean scores (see table 4.18). For PCC scoring, Wilcoxon signed ranks tests showed there were significant differences between accuracy scores on 2 and 3 syllable targets for Mean PCC, RWs and SSs but not for NWs (see table 4.19), where the discrepancy between the children's mean scores on 2 and 3 syllable targets was very small (79.85 and 78.73 respectively).

Table 4.20 Clinical children: comparison between five repetitions accuracy scores on 2 and 3 syllable targets.

	RWs	NWs	SSs	Totals	Mean
Binary	z=-5.053, p<0.001	z=-3.257, p<0.01	z=-4.872, p<0.001	z=-5.323, p<0.001	
PCC	z=-2.049, p<0.05	z=-0.353, p=0.724	z=-4.384, p<0.01		z=-3.387, p<0.001

Key: Key: RWs=real words; NWs=non-words; SSs =syllable sequences; PCC=Percentage Consonants Correct; z=significant at +/-1.65.

There was wide individual variation within the clinical group, using both scoring methods, but particularly on binary scoring (see figure 4.13). On this method, the median score was only 0.67/4 for 3 syllable targets, whereas on PCC scoring it was 79.67. As a result, child 42, who scored very poorly on 3 syllable targets, emerged as an outlier on PCC scoring (see table 4.14) but not on binary scoring. Despite some differences in scores from the two scoring methods, the overall finding was that as a group, the clinical children were significantly more accurate when producing five repetitions of 2 syllable targets than 3 syllable targets.

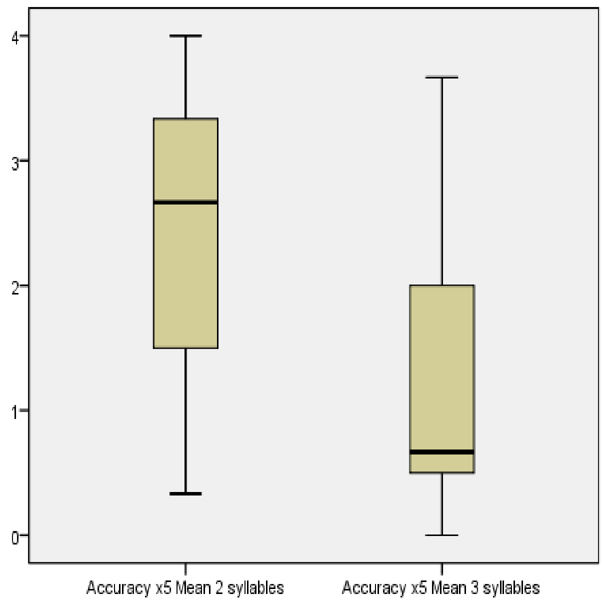


Figure 4.13 Clinical children: Five repetitions accuracy (binary /4) - comparison of the mean totals for 2 and 3 syllable targets.

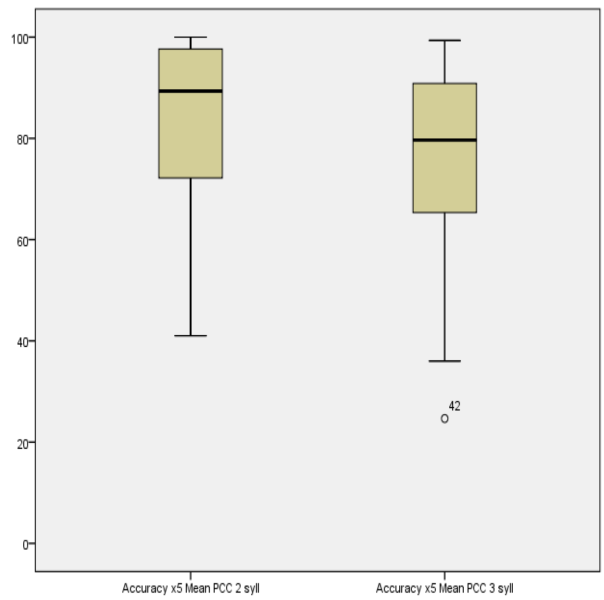


Figure 4.14 Clinical children: Five repetitions accuracy (PCC) - comparison of the mean totals for 2 and 3 syllable targets.

4.4.6 Typical children: Accuracy of five repetitions on 2 and 3 syllable targets

Individual scores from binary and PCC scoring are listed in Appendices 4.19 and 4.20. The results for the typical group from the binary scoring method are presented in table 4.21 and from the PCC method in table 4.22.

Table 4.21 Typical children (n=40) Five repetitions accuracy scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and total mean scores.

Accuracy X 5 Binary /4	RW2	RW3	NW2	NW3	SS2	SS3	Means 2	Means 3
Mean	3.70	3.08	3.31	2.82	3.64	2.56	3.55	2.82
s.d.	.61	.92	.92	1.07	.54	.97	.41	.72
Median	4.00	3.00	4.00	3.00	4.00	3.00	3.67	3.00
Min	2.00	1.00	.00	1.00	2.00	.00	2.33	1.33
Max	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Key: Accuracy x 5= Accuracy of five repetitions; RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

Table 4.22 Typical children (n=40): Five repetitions accuracy scores (PCC) by stimulus length in each stimulus condition and mean totals.

Accuracy X 5 PCC	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	99.55	97.48	97.00	96.31	98.79	95.05	98.44	96.26
s.d.	1.99	4.32	7.26	6.37	3.54	7.45	2.60	4.68
Median	100.00	100.00	100.00	100.00	100.00	98.00	100.00	97.67
Min	88.00	79.00	65.00	74.00	83.00	68.00	88.33	79.00
Max	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Key: Accuracy x 5=Accuracy of five repetitions; RW2=2 syllable real words, RW3=3 syllable real words, NW2=2 syllable non-words, NW3=3 syllable non-words, SS2=2 syllable, syllable sequences, SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d.=standard deviation; min=minimum; max=maximum.

For binary scoring, Wilcoxon matched pairs signed ranks tests showed there were significant differences between accuracy scores on 2 and 3 syllable DDK targets, in all three conditions and for total mean scores (see table 4.21). For PCC scoring, Wilcoxon signed ranks tests showed highly significant differences between accuracy scores on 2 and 3 syllable DDK targets for Mean PCC, RWs, SSs, but not for NWs (see table 4.22), where the discrepancy between the children's mean scores on 2 and 3 syllable targets was very small (97.00 and 96.31 respectively).

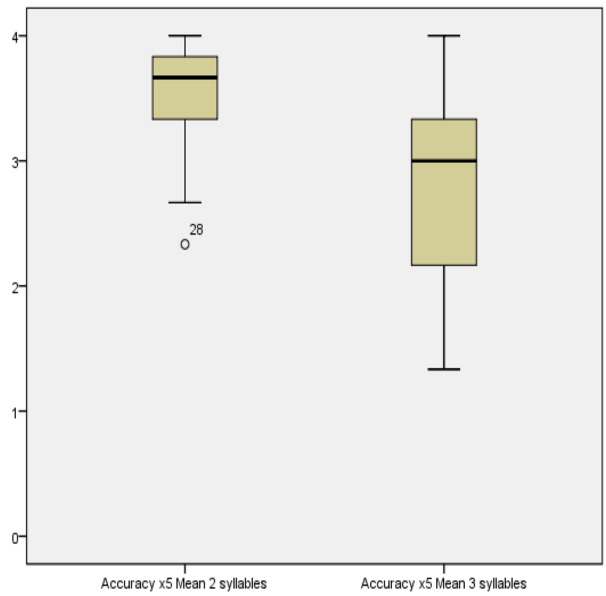
Table 4.23 Typical children: comparison between five repetitions accuracy scores on 2 and 3 syllable targets.

	RWs	NWs	SSs	Totals	Mean
Binary	z=-3.315, $p<0.01$	z=-2.390, $p<0.05$	z=-4.207, $p<0.001$	z=-4.643, $p<0.001$	
PCC	z=-3.278, $p<0.01$	z=-0.869, $p=0.385$	z=-2.925, $p<0.01$		Z=-3.167, $p<0.01$

Key: Key: RWs=real words; NWs=non-words; SSs =syllable sequences; PCC=percentage consonants correct.

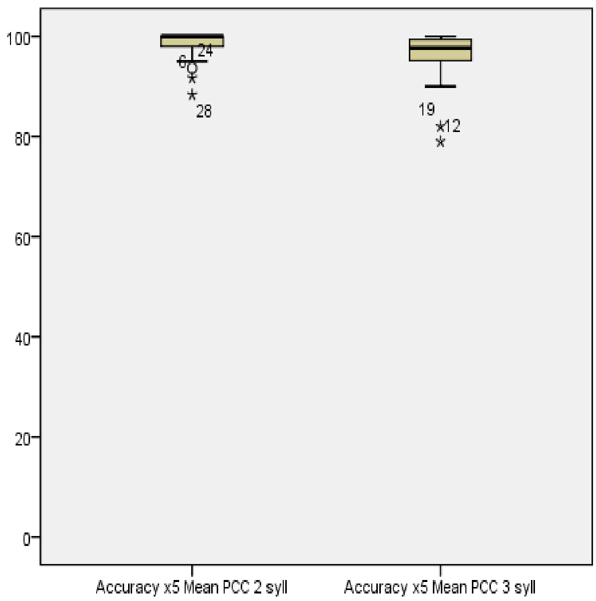
On binary scoring, the typical children's median scores were below ceiling for both 2 and 3 syllable targets (see figure 4.15). Furthermore, there was more evidence of individual variation than on PCC scoring, with the result that only one child (28) emerged as an outlier and this was only on 2 syllable targets. For PCC scoring (see figure 4.16), the median scores of the typical children were at ceiling for 2 syllable targets and close to ceiling for 3 syllable targets. Those few children who scored below this level show as outliers on figure 4.16. There were clearly differences in the results from the two scoring methods, with higher scores being achieved on PCC scoring. This reflects the more flexible nature of PCC scoring, whereby any consonants not produced (e.g. because the child stopped before a run of five repetitions was complete), are removed, still allowing a maximum score to be recorded based on the repetitions that the child did produce. In comparison, on binary scoring, stopping before a run of five repetitions is complete scores 0 point (see chapter three).

Despite the scoring differences, the overall finding was that as a group, the typical children were significantly more accurate when producing five repetitions of 2 syllable targets than 3 syllable targets.



Typical group

Figure 4.15 Typical children: Five repetitions accuracy (binary /4) - comparison of the mean totals for 2 and 3 syllable targets.



Typical children

Figure 4.16 Typical children: Five repetitions accuracy (PCC) - comparison of the mean totals for 2 and 3 syllable targets.

4.4.7 Comparison of clinical and typical children's groups on five repetitions accuracy of 2 and 3 syllable targets

The clinical children were significantly less accurate (binary and PCC) than the typical children ($p<0.001$) on both 2 and 3 syllable targets, in each stimulus condition and for mean totals (see table 4.24).

Table 4.24 Comparison between clinical and typical groups on five repetitions accuracy by stimulus length.

	RW2	RW3	NW2	NW3	SS2	SS3	Mean2	Mean3
Binary	z= -3.916 p<0.001	z= -5.079 p<0.001	z= -4.276 p<0.001	z= -4.399 p<0.001	z= -4.422 p<0.001	z= -5.407 p<0.001	z= -4.784 p<0.001	z= -5.287 p<0.001
PCC	z= -4.956 p<0.001	z= -4.590 p<0.001	z= -4.933 p<0.001	z= -5.252 p<0.001	z= -4.402 p<0.001	z= -5.640 p<0.001	z= -5.028 p<0.001	z= -5.522 p<0.001

Key : RW2= 2 syllable real words; RW3= 3 syllable real words; NW2 =2 syllable non-words; NW3=3 syllable non-words; SS2 =2 syllable, syllable sequences; SS3 =3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; PCC=percentage consonants correct; z=significant at +/- 1.65.

On 2 syllable targets, there was wide individual variation within the clinical group, particularly using the binary scoring method. The typical children's median score was at ceiling on PCC scoring, but not on binary scoring, with the result there was only one outlier on binary scoring but three on PCC. The clinical children scored more poorly than the typical children, whichever scoring method was used (see figures 4.17 and 4.18).

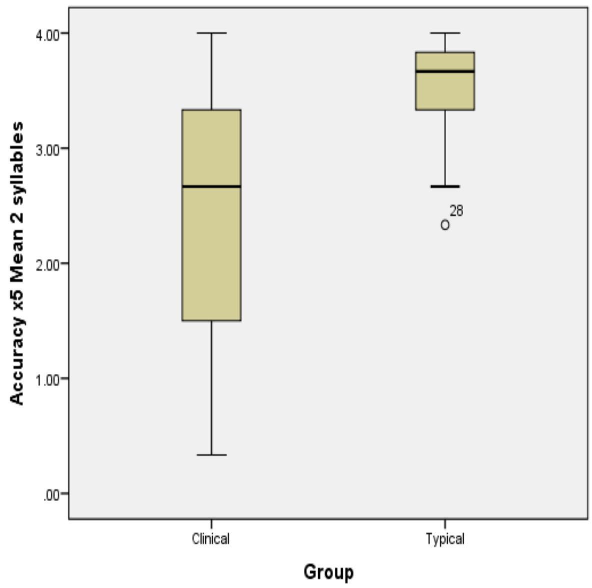


Figure 4.17 Comparison between clinical and typical groups on five repetitions accuracy (binary mean scores) of 2 syllable targets.

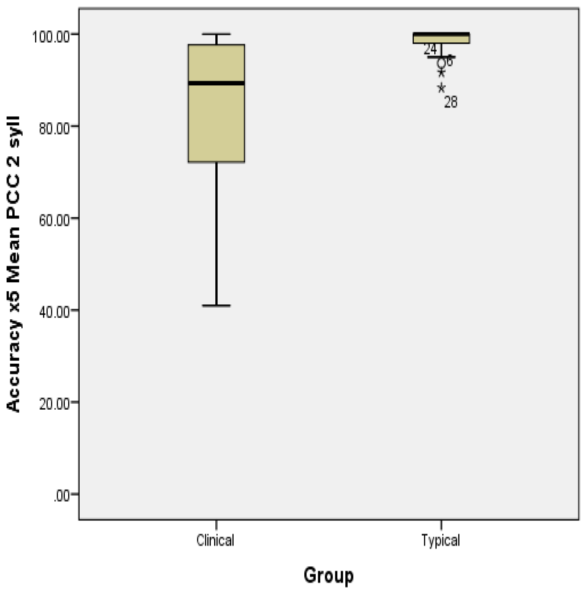


Figure 4.18 Comparison between clinical and typical groups on five repetitions accuracy (PCC mean scores) of 2 syllable targets.

On 3 syllable targets, there was wide individual variation within the clinical group, particularly using the binary scoring method. The typical children's median score was close to ceiling on PCC scoring, but not on binary scoring, with the result there were no outliers on binary scoring but two on PCC. The clinical children scored more poorly than the typical children, whichever scoring method was used (see figures 4.19 and 4.20)

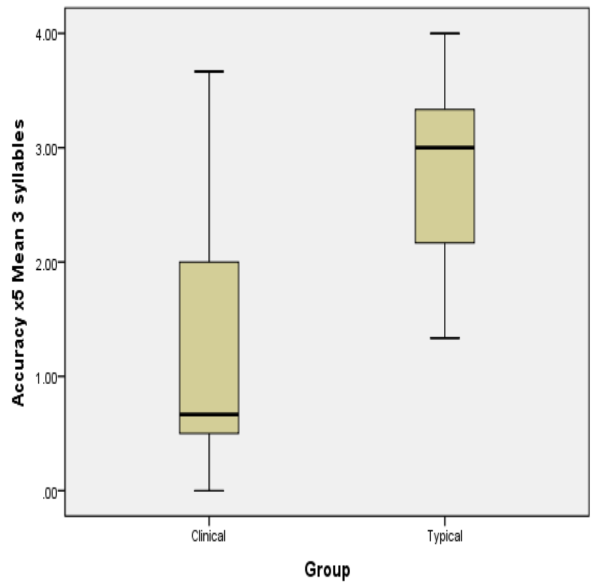


Figure 4.19 Comparison between clinical and typical groups on five repetitions accuracy (binary mean scores) of 3 syllable targets.

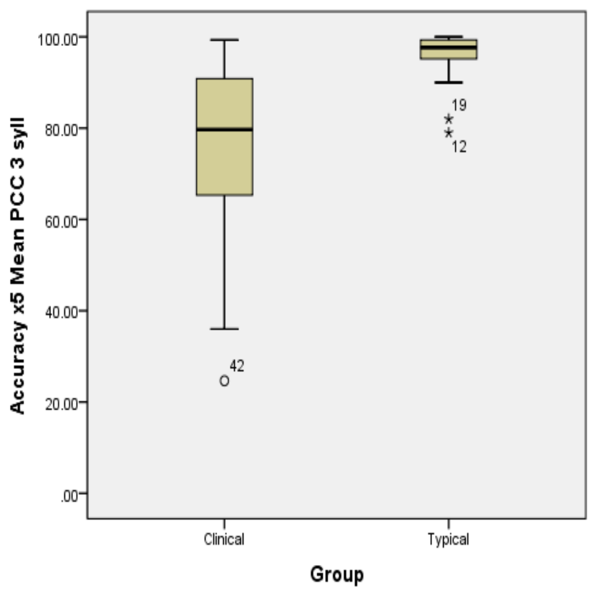


Figure 4.20 Comparison between clinical and typical groups on five repetitions accuracy (PCC mean scores) of 3 syllable targets.

4.4.8 Summary of the results for five repetitions accuracy, by stimulus length:

- There were some differences in scores obtained from the two scoring methods. However, the results overall were similar.
- As groups, the clinical children performed more poorly than the typical children on both 2 and 3 syllable targets

- Both the typical and clinical groups produced 2 syllable targets more accurately than 3 syllable targets, although the differential between the two stimulus lengths was greater for the clinical group.
- There was considerable individual variation within the clinical group and around one quarter of the children scored no differently to the typical children.

4.4.9 Comparison of the summary results for single and five repetitions accuracy, by stimulus length

- There were some differences in scores obtained from the two scoring methods for both single and five repetitions. However, the pattern of results was similar whichever scoring method was used.
- As groups, the clinical children performed more poorly than the typical children on both 2 and 3 syllable targets, for both single and five repetitions.
- The clinical group were more accurate on 2 syllable targets than 3 syllable targets on both single and five repetitions.
- The typical group were as accurate on 2 syllable targets as on 3 syllable targets for single repetitions. However, on five repetitions, they were more accurate on 2 syllable targets than 3 syllable targets.
- There was considerable individual variation within the clinical group with one third of the children scoring no differently to the typical children on single repetitions, but only one quarter scoring no differently to the typical children on five repetitions.

4.5 Chapter four: Summary

Single repetition of a target was an easy task for the typical children, aged 4-7 years, whatever the type of stimulus and whether it was a shorter or longer target. These children also found five repetitions of a DDK target an easy task, whatever the type of stimulus, but particularly if it was a 2 syllable target.

In the clinical group, there was individual variation, but as a group single repetition was easier for these children than five repetitions. Stimulus length affected the children’s performance on both single and five repetitions, with 2 syllable targets being repeated more accurately than 3 syllable targets. In contrast, stimulus type only affected the children’s performance on five repetitions, where they scored more poorly on NW and SS targets than on RWs.

Chapter Five

Results II: DDK Consistency

5.1 Research Questions

The following research questions will be considered in this chapter:

(a)How consistent are a group of children with speech difficulties, aged 4-7 years, on DDK tasks?

(b)How does their consistency on DDK tasks compare to that of age-matched typically-developing children?

5.2 Data

Each child's consistency on each target was scored using the two different scoring methods described in Chapter Three:

(1) binary scoring -1 point for a set of five repetitions in which each repetition matched the child's first imitated response (baseline production) and 0 point if one or more of the repetitions differed. The clinical and typical children's individual scores on each target were recorded. The set of individual scores from the clinical children were combined and compared to the set of combined scores from the typical children for the between group comparisons. Data were analysed by (a) stimulus condition (RW; NW; SS) and (b) stimulus length (2 vs. 3 syllables).

(2) Consistency strength rating - each repetition of a target, within a run of five repetitions, was compared to the child's first imitated response (baseline production) and across the other four repetitions of the same target and scored using a 0-4 point rating system (see Chapter Three, section 3.7.1.5). For each target, the highest number reached across the run of five repetitions was recorded (see worked examples in Chapter Three, tables 3.7i, 3.7ii and 3.7iii). The number of targets that reached a rating of 0, 1, 2, 3 and 4 across the RW, NW and SS conditions, were added together to give total rating scores for an individual child (see Appendix 3.9 for a scoring sheet example). The set of scores which reached ratings 0, 1, 2, 3, 4 from the individual clinical children were combined and compared to the sets of combined scores from the typical children in the between group analyses.

5.3 Stimulus Condition

5.3.1 Clinical children: Consistency of five repetitions (binary scoring)

Individual children's scores obtained from the binary scoring method are listed in Appendix 5.1. There was missing data on one condition for just one child (43) who refused to co-operate for the SS condition and therefore total scores (binary) for this child could not be calculated on full data. The results for the clinical group from the binary scoring method are presented in table 5.1.

Table 5.1 Clinical children (n=40): Binary consistency scores (/8) by stimulus condition and mean totals (/24).

Consistency X 5 Binary	RW /8	NW /8	SS /8	Mean total /24
Mean	5.55	4.80	4.49	14.95
s.d.	1.81	1.90	1.83	4.62
Median	6.00	5.00	4.00	14.00
Minimum	2.00	.00	.00	2.00
Maximum	8.00	8.00	7.00	23.00

Key: Consistency x 5 =Consistency of five repetitions; RW=real words; NW=non-words;
SS =Syllable sequences; s.d. =standard deviation.

Table 5.1 suggests there was individual variation within the group in each of the three stimulus conditions. A Friedman ranks test confirmed this; there were significant differences ($p<0.01$) in the children's consistency scores across the conditions. Post-hoc analyses using Wilcoxon matched pairs signed rank tests showed that the children's mean consistency score on RW targets was significantly higher than on (a) NWs ($z=-2.517$, $p<0.05$) and (b) SSs ($z=-2.918$, $p<0.01$). However, there was no significant difference between their mean scores on NW and SS targets ($z=-1.436$, $p=0.151$).

5.3.2 Typical children: Consistency of five repetitions in RW, NW and SS conditions

Individual children's scores obtained from the binary scoring method are listed in Appendix 5.2. There was missing data for one child (23) who did not complete the NW and SS conditions and therefore total scores could not be calculated on full data. The results for the typical group from the binary scoring method are presented in table 5.2.

Table 5.2 Typical children (n=40): Binary consistency scores (/8) by stimulus condition and mean totals (/24).

Consistency X 5 Binary	RW /8	NW /8	SS /8	Mean total /24
Mean	6.83	6.23	6.36	19.46
S.d.	1.13	1.51	.93	2.39
Median	7.00	6.00	7.00	19.00
Minimum	4.00	2.00	5.00	14.00
Maximum	8.00	8.00	8.00	23.00

Key: Consist x 5 =Consistency of five repetitions; RW=real words; NW=non-words; SS =Syllable sequences; s.d. =standard deviation.

There was individual variation within the group in each of the three stimulus conditions. A visual inspection of the data in Table 5.2 suggested there might be significant differences in the children's consistency across the conditions. In particular, that the children were significantly more consistent in the RW condition than in the NW and SS conditions. Post-hoc analyses using Wilcoxon matched pairs signed rank tests showed that there were no significant differences, between the typical children's consistency scores in any of the three stimulus conditions (RWs and NWs: z=-1.933, p=.053; RWs and SSs: z=-1.775, p=.076; NWs and SSs: z=-.495, p=.620). However, the difference between the children's scores in the RW and NW conditions was approaching significance.

5.3.3 Comparison between clinical and typical children as groups on consistency scores (binary scoring) across the stimulus conditions

The mean consistency scores (/8) of the clinical and typical groups were compared in each of the three stimulus conditions. Results of Mann-Whitney U tests showed highly significant differences between the two groups in each of the three conditions: RW (z=-3.252, p<0.01), NW (z= -3.481, p<0.001) and SS (z=-4.625, p<0.001). Thus, the results show that the clinical children were significantly less consistent than the typical children in all three stimulus conditions.

When the total mean consistency scores (/24) of the clinical children were compared to those of the typical children, a highly significant difference was also found (z= -4.644, p<0.001) and this is illustrated in figure 5.1. As for the individual stimulus conditions, the clinical children were significantly less consistent than the typical children.

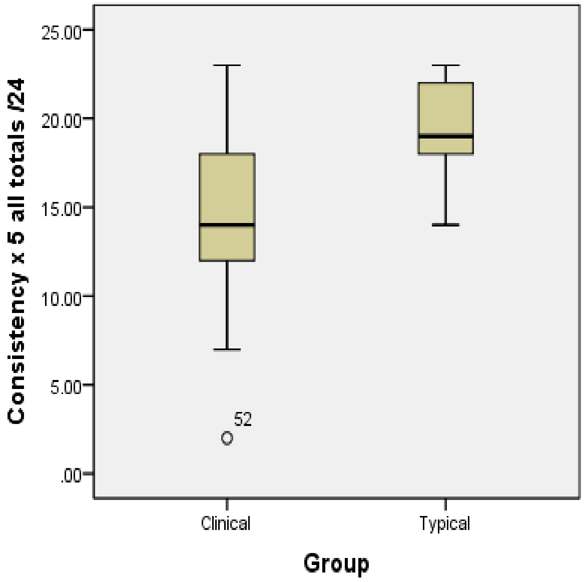


Figure 5.1 Comparison between the total mean consistency scores (/24) obtained by the clinical and typical groups.

5.3.4 Individual clinical children's scores compared to the typical group mean scores on consistency (binary scoring) across the stimulus conditions

Each clinical child's combined total score (binary /24) for consistency, was compared to the combined mean total scores of the typical group and z scores were calculated. The z scores obtained by the individual clinical children are listed in Appendix 5.3 and are summarised in table 5.3.

Table 5.3 Summary of significance of individual clinical children's consistency scores (binary total /24) compared to typical group means.

	No. of children
Missing	1 (2.5%)
Not significant	1 (47.5%)
Any level of significance	20 (50%)

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Half of the clinical children (50%) scored significantly differently to the mean scores of the typical group, whereas just under half (47.5%) scored no differently and there was missing data for one child (2.5%). When the levels of significance were examined for the children who performed significantly differently to the typical group, 17/20 (85%) were at a highly significant level (p<0.01 or p<0.001 level).

The median score of the typical group (19/24) was higher than that of the clinical group (14/24). Furthermore, there was more variation within the clinical group's scores. One child (Child 52) was an outlier, scoring outside the range of the other clinical children.

5.3.5 Clinical children: Consistency of five repetitions (consistency strength rating)

The consistency strength rating scores from the individual DDK targets were combined across the stimulus conditions (RWs, NWs and SSs). The scores for each clinical child are listed in Appendix 5.4 and the results for the clinical group are presented in table 5.4.

Table 5.4 Clinical children (n=40): consistency strength rating scores 0-4 (/24).

	Rating 0 /24	Rating 1 /24	Rating 2 /24	Rating 3 /24	Rating 4 /24
Mean	4.26	15.05	3.49	.85	.33
s.d.	3.41	4.58	2.48	1.29	.77
Median	4.00	15.00	3.00	.00	.00
Minimum	.00	2.00	.00	.00	.00
Maximum	14.00	23.00	9.00	6.00	4.00

Key: rating 0=did not produce five repetitions; rating 1=repetition identical to child's baseline; rating 2=repetition different to child's baseline; rating 3=repetition different to child's baseline and to one other previous repetition; rating 4=repetition different to child's baseline and to two other previous repetitions.

The clinical children were generally consistent in their DDK repetitions, when scored in comparison to their own speech sound system. Despite some individual variation within the clinical group, a consistency rating of 1 (repetition identical to the child's baseline production) was the most common rating (see figure 5.2). This was followed by a rating of 0 (child did not complete five repetitions of a given target), and then a rating of 2 (repetition different to child's baseline production). Few children obtained ratings of 3 (repetition different from child's baseline production and from one other previous repetition) or 4 (repetition different from child's baseline production and from two other previous repetitions).

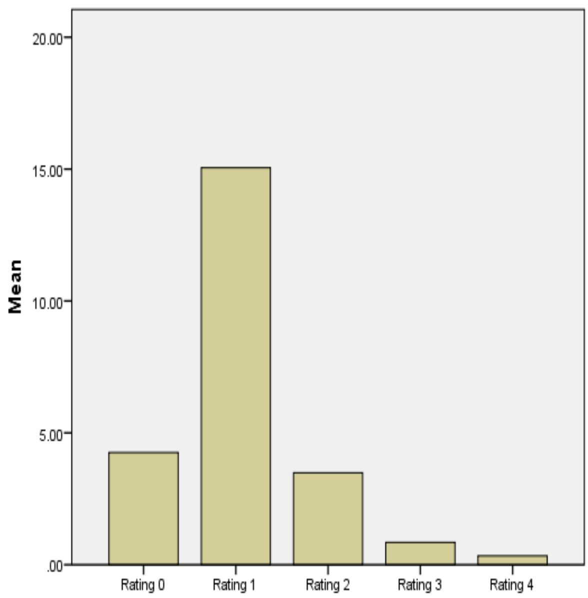


Figure 5.2 Clinical children: total mean (/24) consistency strength ratings of 0-4, across the stimulus conditions (RWs, NWs & SSs).

5.3.6 Typical children: Consistency of five repetitions (consistency strength rating)

The consistency strength rating scores from the individual DDK targets were combined across the stimulus conditions (RWs, NWs and SSs). The scores for each typical child are listed in Appendix 5.5 and the results for the typical group are presented in table 5.5.

Table 5.5 Typical children (n=40): consistency strength rating scores 0-4 (/24).

	Rating 0 /24	Rating 1 /24	Rating /24	Rating 3 /24	Rating 4 /24
Mean	2.36	19.26	1.87	.44	.10
s.d.	1.88	2.64	1.59	.64	.50
Median	2.00	19.00	1.00	.00	.00
Minimum	.00	14.00	.00	.00	.00
Maximum	9.00	23.00	8.00	2.00	3.00

Key: rating 0=did not produce five repetitions; rating 1=repetition identical to child's baseline; rating 2=repetition different to child's baseline; rating 3=repetition different to child's baseline and to one other previous repetition; rating 4=repetition different to child's baseline and to two other previous repetitions.

Despite some individual variation, a consistency rating of 1 (repetition identical to the baseline production) was by far the most common rating (see figure 5.3). This was followed by a rating of 0, (child did not complete five repetitions of a given DDK target), and then a rating of 2 (repetition different to child's baseline production). Few children obtained ratings of 3 (repetition different from child's baseline production and from one other previous repetition) or 4 (repetition different from child's baseline production and from two other previous repetitions).

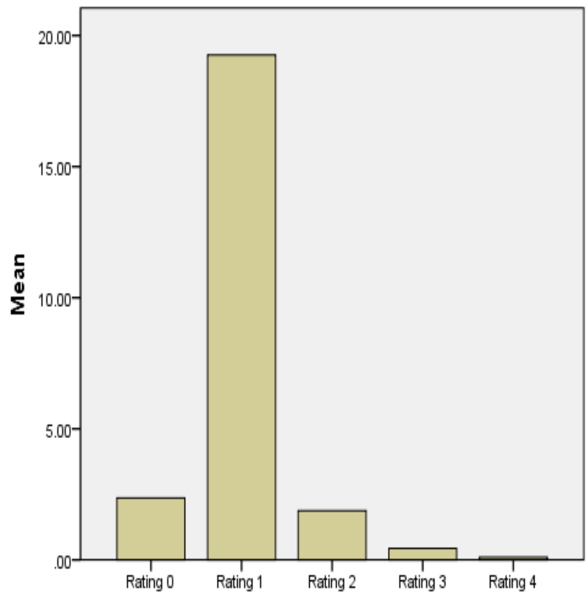


Figure 5.3 Typical children: total mean (/24) consistency strength ratings of 0-4, across the stimulus conditions (RWs, NWs & SSs).

5.3.7 Comparison between clinical and typical children as groups on consistency strength rating

A Kruskal Wallis test was conducted to compare the ratings obtained by the clinical group and the typical group (see table 5.6).

Table 5.6: Clinical (n=40) children compared to typical (n=40) children as groups on consistency strength ratings 0-4.

Test Statistics[a,b]

	Rating 0	Rating 1	Rating 2	Rating 3	Rating 4
Chi-Square	7.723	18.879	9.216	1.756	4.910
df	1	1	1	1	1
Asymp. Sig.	.005	.000	.002	.185	.027

a. Kruskal Wallis Test

b. Grouping Variable: Clinical or typical group

Significant or highly significant differences were found, between the groups, for all ratings, except for rating 3. The results show that the clinical children generally had significantly lower consistency ratings than the typical children. Thus, although both groups of children were generally consistent, the clinical group were significantly less consistent than the typical group. Furthermore, the clinical group were significantly less likely to complete five repetitions of a given DDK target (therefore scoring a rating of 0) than the typical group.

5.3.8 Summary of results for Consistency of DDK targets by stimulus condition

- There was individual variation in consistency within both groups, but more so in the clinical than the typical group.
- On binary scoring, the clinical group obtained significantly lower consistency scores than those of the typical group on RWs, NWs & SSs and on combined totals.
- As a group, the clinical children were significantly more consistent on RWs than on NWs and SSs.
- As a group, the typical group were equally consistent on RWs, NWs and SSs.
- Individual findings for the clinical children showed that 47.5% were as consistent as the typical children on combined total consistency scores (binary /24).
- On a consistency strength rating, both the clinical and typical groups were generally consistent i.e. they produced a rating of 1 (repetition identical to child baseline) far more commonly than any other rating. However, the clinical children scored significantly lower on rating 1 than the typical children: 15.05/24 vs. 19.26/24, demonstrating a quantitative but not a qualitative difference.

5.4 Stimulus Length

5.4.1 Clinical children: Consistency of five repetitions (binary scoring)

Individual scores from the binary scoring method are listed in Appendix 5.6. There was missing data for child 43, who did not co-operate for SSs and therefore mean scores for this child could not be calculated on full data. The results for the clinical group from the binary scoring method are presented in table 5.7.

Table 5.7: Clinical children (n=40): Consistency scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and mean totals.

Consistency X 5 Binary /4	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	3.43	2.13	2.65	2.15	2.74	1.69	2.94	2.00
S.d.	.71	1.24	1.12	1.37	1.04	1.06	.73	.93
Median	4.00	2.00	3.00	2.00	3.00	2.00	3.00	2.00
Min	2.00	.00	.00	.00	.00	.00	.67	.00
Max	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Key: Consistency X 5= Consistency of 5 repetitions; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d. =standard deviation; min=minimum; max=maximum

There was considerable variation within the clinical group on both stimulus lengths. For 2 syllable targets, a Friedman ranks test showed there were significant differences ($p<0.01$) in the children's consistency across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests showed that the children were significantly more consistent when producing 2-syllable RWs than NWs ($z=-3.384$, $p<0.01$) or SSs ($z=-3.259$, $p<0.01$), but there were no significant differences between consistency of NWs or SSs ($z=-.498$, $p=0.618$). For 3 syllable targets, a Friedman ranks test showed there were no significant differences ($p=.076$) across the conditions.

For the mean consistency scores, across the conditions (RWs, NWs & SSs), of 2 and 3 syllable targets, a Wilcoxon signed ranks test showed there was a highly significant difference ($z=-4.977$, $p<0.001$). The clinical children repeated 2 syllable targets more consistently than 3 syllable targets (see figure 5.4).

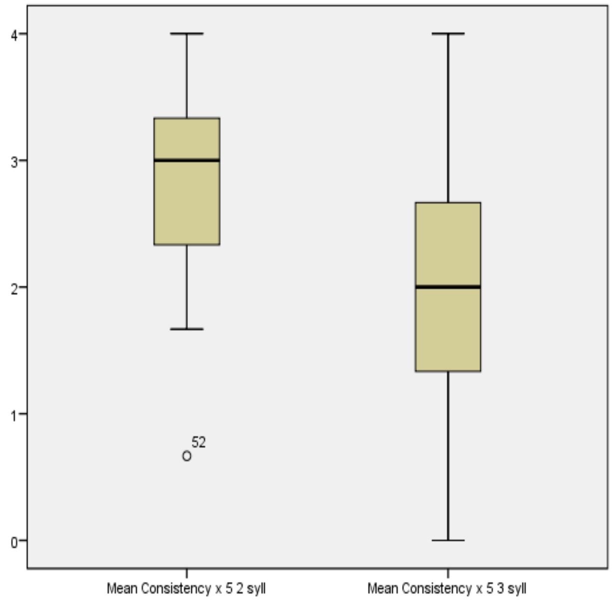


Figure 5.4. Clinical children: comparison between mean consistency scores (binary /4) of 2 and 3 syllable targets.

Within the clinical group, there was individual variation on both stimulus lengths but particularly on 3 syllable targets. Child 52 was an outlier on 2 syllable targets, scoring below the overall group performance, but not on 3 syllable targets, where there was a much wider spread of scores.

5.4.2 Typical children: Consistency of five repetitions (binary scoring)

Individual scores from the binary scoring method are listed in Appendix 5.7. There was missing data for child 23, who did not complete NWs and SSs and therefore mean scores for this child could not be calculated on full data. The results for the typical group from the binary scoring method are presented in table 5.8.

Table 5.8 Typical children (n=40): Consistency scores (binary /4) by stimulus length (2 vs. 3 syllables) in each stimulus condition and mean totals.

Consist. X 5 Binary /4	RW2	RW3	NW2	NW3	SS2	SS3	Mean2	Mean3
Mean	3.73	3.10	3.33	2.90	3.69	2.67	3.58	2.89
s.d	.60	.87	.93	.94	.47	.84	.38	.62
Median	4.00	3.00	4.00	3.00	4.00	3.00	3.67	3.00
Minimum	2.00	1.00	.00	1.00	3.00	1.00	2.67	1.67
Maximum	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Key: Consist x5. =Consistency of 5 repetitions; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; s.d. =standard deviation.

There was considerable variation within the group for both stimulus lengths. For 2 syllable targets, a Friedman ranks test showed there were no significant differences ($p=.070$) in the children's consistency across the conditions. For 3 syllable targets, a Friedman ranks test showed there were significant differences ($p<0.05$) across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests showed that the typical children produced RWs significantly more consistently than SSs ($z=-2.604$, $p<0.01$) but there were no significant differences in their consistency of RW and NW production ($z=-1.079$, $p=.280$) or NWs and SSs ($z=-1.175$, $p=.240$).

For the mean consistency scores (across conditions) of 2 and 3 syllable targets, a Wilcoxon signed ranks test showed there was a highly significant difference ($z=-4.714$, $p<0.001$). The typical children repeated 2 syllable targets more consistently than 3 syllable targets (see figure 5.5). Furthermore there was more individual variation on 3 syllable targets than on 2 syllable targets.

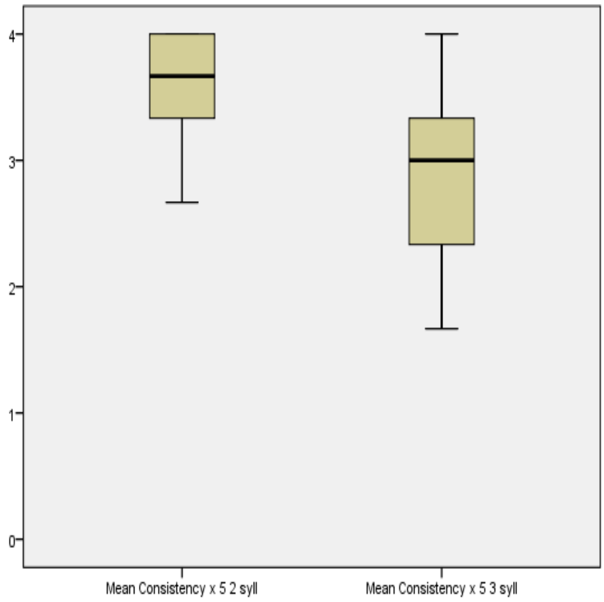


Figure 5.5 Typical children: comparison between mean consistency scores (binary /4) of 2 and 3 syllable targets.

5.4.3 Comparison between clinical and typical children as groups on consistency scores by stimulus length

The consistency scores of the clinical children were significantly ($p<0.001$) lower than those of the typical children for both 2 and 3 syllable targets ($z=-4.221$ and $z=-4.299$ respectively) –see figures 5.6. and 5.7.

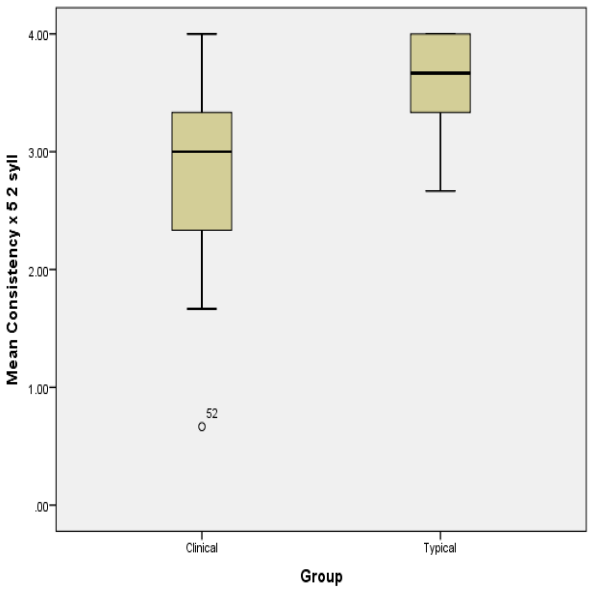


Figure 5.6 Comparison between clinical and typical groups on mean consistency scores (/4) for 2 syllable targets.

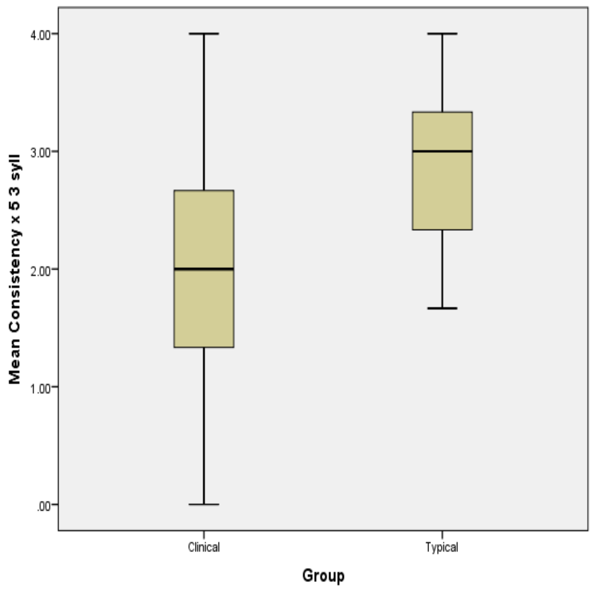


Figure 5.7 Comparison between clinical and typical groups on mean consistency scores (/4) for 3 syllable targets.

On 2 syllable targets, the median score of the typical group was higher than that of the clinical group and there was less individual variation within the typical group than the clinical group. Child 52 was again an outlier in the clinical group, scoring below the overall group's scores. On 3 syllable targets, the median score of the typical group was higher than that of the clinical group. There was more individual variation within both groups and especially within the clinical group, with the result that there were no outliers at this stimulus length.

5.4.4 Individual clinical children's scores compared to the typical group mean scores on consistency, by stimulus length (binary scoring)

Each clinical child's mean consistency score (binary /4) for 2 and 3 syllable targets, was compared to the mean consistency scores of the typical group and z scores were calculated. The z scores obtained by the individual clinical children are listed in Appendix 5.8 and are summarised in table 5.9.

Table 5.9 Summary of significance of individual clinical children's consistency scores (binary mean /4) by stimulus length (2 vs. 3 syllables) compared to typical group means.

	Mean 2 syllables	Mean 3 syllables
Missing	1 (2.5%)	1 (2.5%)
Not significant	23 (57.5%)	20 (50%)
Any level of significance	16 (40%)	19 (47.5%)*

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level. * One child scored above the group means at a significant level.

The results showed that on 2 syllable targets, 40% of the clinical children scored significantly differently to the mean scores of the typical group, and on 3 syllable targets, this number increased to 47.5%. When the levels of significance were examined for the children who performed significantly differently to the typical group, all 16 children scored differently at a highly significant level (p<0.01 or p<0.001 level) on 2 syllable targets. However, only 11/19 children scored differently at a highly significant level (p<0.01 or p<0.001 level) on 3 syllable targets. This difference in results on 2 and 3 syllable targets is probably explained by the differentiated performance of the typical children. As a group, they showed more individual variation on 3 syllable than 2 syllable targets and their mean scores were significantly lower on 3 syllable than on 2 syllable targets.

5.4.5 Summary of main findings for consistency of five repetitions by stimulus length (binary scoring)

- There was individual variation within both the clinical and typical groups, and particularly on 3 syllable targets.
- As groups, both the clinical and typical children were significantly more consistent on 2 syllable targets than 3 syllable targets.
- As groups, the clinical children were significantly less consistent than the typical children on both 2 and 3 syllable targets.
- Individual findings for the clinical children showed that 57.5% were as consistent as the typical children on 2 syllable targets, whereas 50% were as consistent as the typical children on 3 syllable targets.

5.5 Summary of main findings for consistency

Although there was individual variation, the clinical group were significantly less consistent than the typical group (on binary scoring) in each stimulus condition (RWs, NWs and SSs) and on mean totals across the stimulus conditions. Within the clinical group, the children were significantly more consistent on RWs than on NWs and SSs, whereas within the typical group, the children were equally consistent on RWs, NWs and SSs. On the consistency strength ratings, both the clinical and typical groups produced a consistency rating of 1 (i.e. repetition identical to the baseline production) far more commonly than any other rating. However, when the performance of the two groups was compared, the clinical children had lower consistency strength ratings than the typical children, on all except one rating. Both groups of children were more consistent on shorter, 2 syllable targets than on longer, 3 syllable targets. Some individual clinical children scored much lower scores in comparison to the typical group on 2 syllable, 3 syllable and/or on all targets.

Chapter Six
Results III: DDK Rate

6.1 Research questions

The following research questions will be considered in this chapter:

(a) What is the rate of production on DDK tasks of a group of children (CA: 4-7 years) with speech difficulties?

(b) How does their rate of production on DDK tasks compare to that of age-matched typically-developing children?

6.2 Data

Each child's rate in seconds / milliseconds per syllable on each target was recorded as described in Chapter Three, section 3.7.1.6. The rates of the clinical children as a group were then compared to those of the typical children as a group. Data for between group comparisons were analyzed by (a) stimulus condition (RW; NW; SS) and mean rate across the conditions and (b) stimulus length (2 vs. 3 syllables). A further analysis was made of the number of repetitions (N= /a total of 5) produced by the children by stimulus length and condition. The rate measures from each individual child with speech difficulties were also compared to the mean overall rates of the typical group.

6.3 Stimulus Condition

6.3.1 Clinical group: Rates for five repetitions in RW, NW and SS condition

Individual clinical children's rates are listed in Appendix 6.1. There was missing data for just one child (43) who refused to co-operate on the SS condition and therefore mean rates were calculated on 39 rather than 40 children. The rate results for the clinical group in each condition and as a mean rate across the conditions are presented in table 6.1.

Table 6.1 Clinical group (n=40): mean rate scores in seconds per syllable in each stimulus condition and mean rates across the conditions.

Rate Secs/syll:	RW	NW	SS	Mean
Mean	.29	.32	.31	.31
s.d.	.06	.07	.08	.07
Median	.29	.32	.29	.29
Minimum	.18	.20	.20	.19
Maximum	.53	.53	.60	.55

Key: RW=real words; NW =non-words and SS=syllable sequence; s.d.=standard deviation.

There was individual variation within the group in all stimulus conditions and in the mean rate, across the conditions. A Friedman ranks test showed that there were significant differences ($p<0.05$) in the children's rate scores across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests revealed that RWs were produced significantly faster than NWs ($z=-2.840$, $p<0.05$) but there were no significant differences between rates for RWs and SSs ($z=-1.786$, $p=.074$) or NWs and SSs ($z=-1.682$, $p=.093$).

6.3.2 Typical group: Rates for five repetitions in RW, NW and SS condition

Individual typical children's rates are listed in Appendix 6.2. There was missing data for one child (23) who did not complete the NW and SS conditions therefore mean rates were calculated on 39 rather than 40 children. The rate results for the typical group in each condition and as a mean rate across the conditions are presented in table 6.2.

Table 6.2 Typical group (n=40): mean rate scores in seconds per syllable in each stimulus condition and mean rates across the conditions.

Rate Secs/syll:	RW	NW	SS	Mean
Mean	.23	.25	.22	.23
s.d.	.04	.05	.04	.04
Median	.22	.24	.23	.24
Minimum	.17	.18	.15	.17
Maximum	.33	.37	.32	.34

Key: RW=real words; NW =non-words and SS=syllable sequence; s.d.=standard deviation.

There was individual variation within the group in all stimulus conditions and in the mean rate. A Friedman ranks test confirmed that there were significant differences ($p<0.001$) in the children's rate scores across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests revealed that RWs and SSs were produced significantly faster than NWs ($z=-3.907$, $p<0.001$; $z=-4.431$, $p<0.001$) but there was no significant difference between rates for RWs and SSs ($z=-1.954$, $p=.051$).

6.3.3 Comparison of clinical and typical groups on DDK rates by stimulus condition

The rates of the clinical group were significantly slower ($p<0.001$) than the typical group in all stimulus conditions (RWs, $z=-5.018$, SSs, $z=-4.687$, SSs, $z=-5.471$) and for the overall mean rate ($z=-5.331$). The overall mean rates of the clinical and typical groups are compared in figure 6.1.

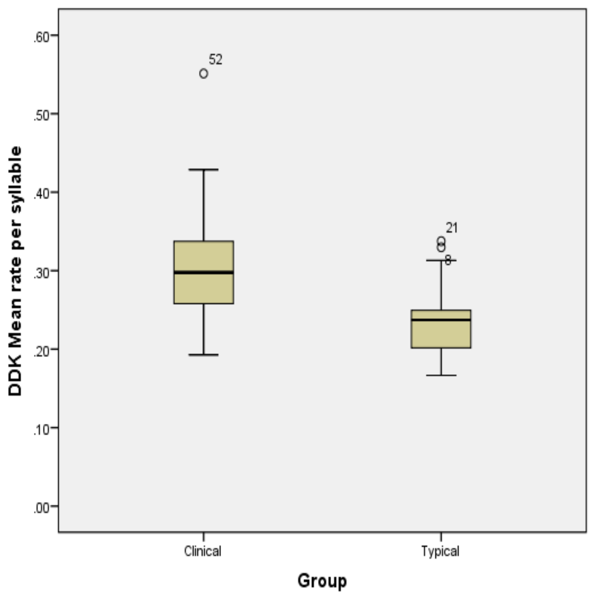


Figure 6.1 Mean DDK rates: comparison between clinical and typical groups across all conditions.

There was variation in rates within both groups, but the median scores of the typical group were lower (i.e. they produced faster rates) than those of the clinical group. In the typical group, there were two outliers (Children 8 and 21) who produced slower mean rates (.33 and .34 respectively) than the rest of the typical group (.23). In the clinical group, one child (52) was an outlier, but an extreme one. He produced a much slower mean rate (.55) than the rest of the clinical group (.31).

6.3.4 Comparison between individual clinical children's rates and the typical group's mean rate

Each individual clinical child's DDK mean rate (across the RW, NW and SS conditions) was compared to the typical group's mean rate of .23 (s.d. =.04). Z scores and levels of significance were calculated. The scores are listed in Appendix 6.3 and the results are summarised in table 6.3.

Table 6.3 Individual clinical children (n=40) in comparison to the typical group's mean rates (measured as rate per syllable in seconds): summary of significance levels for z scores.

	DDK mean rate (per syllable in seconds)
Missing data	1 (2.5%)
Not significant	20 (50%)
Any level of significance	19 (47.5%)

The results demonstrate that the clinical children did not perform as a homogeneous group. Twenty of the children (50%) performed similarly to the typical children on DDK mean rate, whereas nineteen children (47.5%) performed significantly less well. Thirteen of these nineteen clinical children performed differently to the typical children at a highly significant level ($p<0.01$ or $p<0.001$). Examination of the individual children's rates (see Appendix 6.1) indicates that this finding cannot simply be explained by maturity alone, as the children who performed poorly on rate are spread across the age range. Rather it indicates that one or more subgroups of children may exist within the clinical group who have specific difficulties with DDK rate.

6.3.5 Summary of the results for DDK rate by stimulus condition

- The clinical group produced a mean rate of .31 seconds per syllable (or 3.23 syllables per second) and the typical group produced a mean rate of .23 seconds per syllable (or 4.35 syllables per second). Thus, as a group, the clinical children were significantly slower than the typical children in overall mean rate across the conditions.
- Within the clinical group, RWs were produced faster than NWs, but there were no differences in rates for RWs and SSs or for NWs and SSs.
- Within the typical group, both RWs and SSs were produced faster than NWs, but there were no differences in rates for RWs and SSs.
- There was individual variation within the clinical group and only 50% of the children performed significantly differently to the typical group on overall mean rate. This finding did not appear to simply reflect age and maturity.

6.4 Stimulus Length

6.4.1 Clinical group: Rates for five repetitions by stimulus length (2 vs. 3 syllables)

Individual clinical children's rates are listed in Appendix 6.4. There was missing data for one child (43) who refused to co-operate on the SS condition and therefore mean rates could not be calculated on full data. Furthermore, child 52 attempted all SS targets but made so many syllable omissions on the 3 syllable targets, that it was not possible to record rates on this stimulus length in a meaningful way. He also produced the slowest RW and NW rates for 3 syllable targets of all the clinical children: .55 and .60 seconds respectively (see maximum rates in table 6.4). In comparison, the group maximum rate for 3 syllable SSs is .46 seconds (i.e. significantly lower than RW and NW rates), and probably reflects the excluded SS data from child 52.

The rate results for the clinical group for each stimulus length in each condition and as a combined mean rate for 2 and 3 syllable targets, across the conditions are presented in table 6.4.

Table 6.4 Clinical children (n=40): mean rates in seconds per syllable for each stimulus length in each stimulus condition and combined mean rates for 2 and 3 syllables items.

Mean Rate Secs/ syll:	RW2	RW3	NW2	NW3	SS2	SS3	Comb. 2 syllables	Comb. 3 syllables
Mean	.28	.31	.30	.33	.30	.30	.29	.31
s.d.	.07	.07	.08	.08	.08	.06	.07	.06

Median	.27	.30	.28	.31	.28	.29	.28	.30
Min	.17	.18	.17	.21	.20	.19	.19	.20
Max	.52	.55	.52	.60	.60	.46	.53	.44

Key: RW2 =2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Secs=seconds; Syll=syllable; s.d.= standard deviation; min=minimum; max=maximum.

There was considerable variation within the clinical group for both stimulus lengths in all stimulus conditions and in the combined mean rates. For 2 syllable targets, a Friedman ranks test showed that there were significant differences ($p<0.05$) in the children's rates across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests confirmed that 2-syllable RWs were produced significantly faster than 2 syllable NWs ($z=-2.124$, $p<0.05$) and SSs ($z=-3.112$, $p<0.01$) but there were no significant differences between rates for 2 syllable NWs and SSs ($z=-0.230$, $p=.818$). For 3 syllable targets, a Friedman ranks test showed that there were significant differences ($p<0.01$) in the children's rates across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests showed that 3 syllable RWs and SS were produced significantly ($p<0.01$) faster than 3 syllable NWs ($z=-2.836$ for RWs and $z=-2.683$ for SSs), but there was no significant difference ($z=-0.247$, $p=.805$) in the rates for 3 syllable RWs and SSs.

For the combined mean rates, a Wilcoxon signed ranks test showed that there was a significant difference ($z=-3.676$, $p<0.001$) in the clinical group's mean rates by stimulus length. Two syllable targets were produced faster than three syllable targets (see figure 6.2).

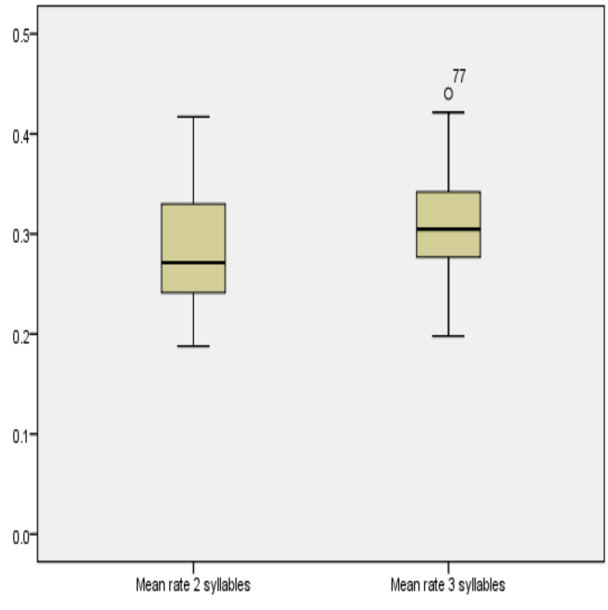


Figure 6.2 Clinical group: comparison between DDK rates for 2 and 3 syllable targets.

There was individual variation for both stimulus lengths and one child (77) was an outlier on 3 syllable targets, due to his slow production rate (.44 seconds compared to group mean of .31 seconds). Child 52 who produced very slow rates on RW and NW 3 syllable targets, does not appear as an outlier as his data was excluded from the mean rate calculations, since his rates on SS targets could not be recorded.

6.4.2 Typical group: Rates for five repetitions by stimulus length (2 vs. 3 syllables)

Individual typical children's rates are listed in Appendix 6.5. There was missing data for one child (23) who only completed RWs and therefore mean rates were calculated on 39 rather than 40 children.

The rate results for the typical group for each stimulus length in each condition and as a combined mean rate for 2 and 3 syllable targets across the conditions are presented in table 6.5.

Table 6.5 Typical group (n=40): rates in seconds per syllable for each stimulus length in each stimulus condition and combined mean rates.

Mean rate Secs/syll:	RW2	RW3	NW2	NW3	SS2	SS3	Comb. 2 syllables	Comb. 3 syllables
Mean	.23	.23	.24	.25	.23	.22	.23	.23
s.d.	.06	.03	.06	.05	.05	.04	.05	.04
Median	.21	.23	.24	.25	.23	.21	.23	.23
Min	.15	.18	.15	.18	.13	.13	.15	.17
Max	.40	.34	.41	.41	.34	.31	.37	.35

Key: RW2 =2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Secs=seconds; Syll=syllable; comb=combined totals; s.d.= standard deviation; min=minimum; max=maximum.

There was individual variation within the group for both stimulus lengths in all stimulus conditions and in the combined mean rates. For 2 syllable targets, a Friedman ranks test showed that there were significant differences ($p<0.01$) in the children's rates across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests showed that 2-syllable RWs and SSs were produced significantly faster that 2-syllable NWs ($z=-3.015$, $p<0.012$ for RWs and $z=-2.366$, $p<0.05$ for SSs) but there were no significant differences in the rates for 2 syllable RWs or SSs ($z=-0.377$, $p=.706$). For 3 syllable targets, a Friedman ranks test showed that there were significant differences ($p<0.001$) in the children's rates across the conditions. Post-hoc analyses using Wilcoxon signed ranks tests showed that 3 syllable RWs and SSs were produced significantly faster than 3 syllable NWs (z=-3.782, p<0.001 for RWs and z= -5.066, p<0.001 for SSs). Furthermore, 3 syllable SSs were produced significantly faster than 3 syllable RWs (z=-3.322, p<0.01).

In contrast to the performance of the clinical group who produced 2 syllable targets faster than 3 syllable targets, a Wilcoxon signed ranks test showed no significant difference (z=-0.335, p=0.738) in the typical children's mean rates on 2 syllable and 3 syllable items (see figure 6.3). However, figure 6.3 shows there was a slightly wider range of rates on 2 syllable than on 3 syllable targets. This resulted in there being no outliers on 2 syllable targets but two outliers emerged on 3 syllable targets.

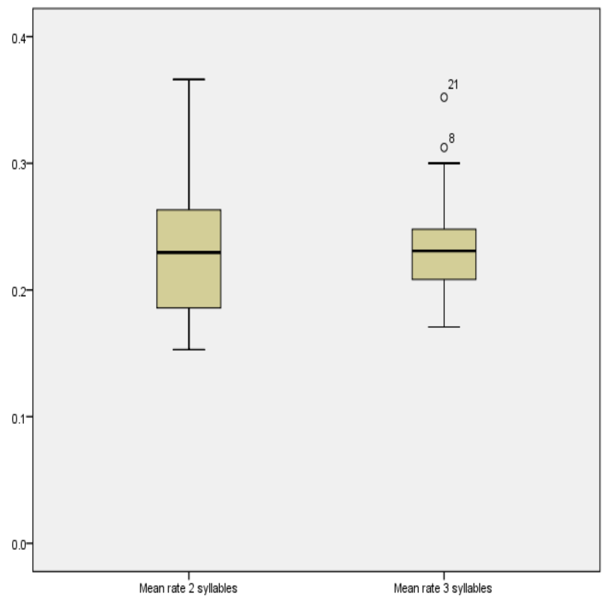


Figure 6.3 Typical group: comparison between DDK rates for 2 and 3 syllable targets.

6.4.3 Comparison of clinical and typical groups on DDK rates by stimulus length

The combined mean rates of the clinical group were significantly slower (p<0.001) than the typical group in both stimulus lengths: 2 syllables (z=-4.068) and 3 syllables (z=-5.920) – see figures 6.4 and 6.5. On 2 syllable targets, there was individual variation in both groups but the typical group's median score was faster than that of the clinical group. There was one outlier in the clinical group, Child 52 who produced a much slower rate (.53) than the group mean rate (.29).

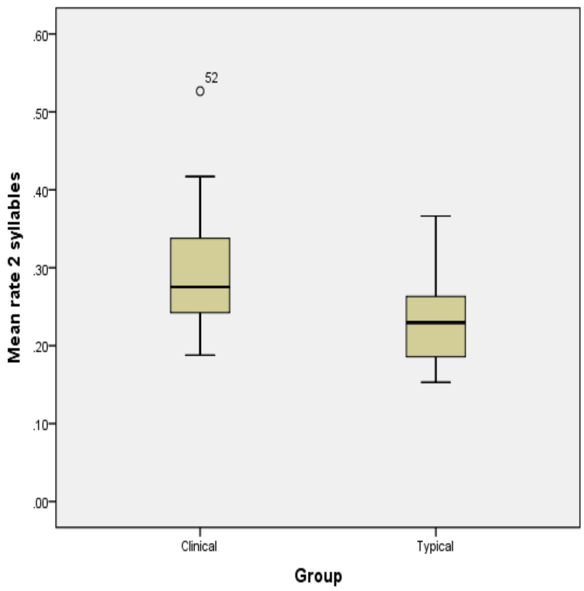


Figure 6.4 Combined mean rate for 2 syllable targets: comparison between clinical and typical groups.

On 3 syllable targets, there was individual variation in both groups but more in the clinical group (see figure 6.5). The typical group's median score was significantly faster than that of the clinical group. There were two outliers in the typical group (children 8 and 21) who produced slower rates (.31 and .35 respectively) than the group mean rate (.23). There was also one outlier in the clinical group, Child 77, who produced a slower rate (.44) than the group mean rate (.31). Child 52 , who was an outlier for 2 syllable targets, had missing data for 3 syllable targets and therefore does not show up as an outlier at this stimulus length. However, inspection of his raw scores in Appendix 6.4, shows that he was very slow on the 3 syllable targets that he tried to produce (RWs =.55 & NWs =.60).

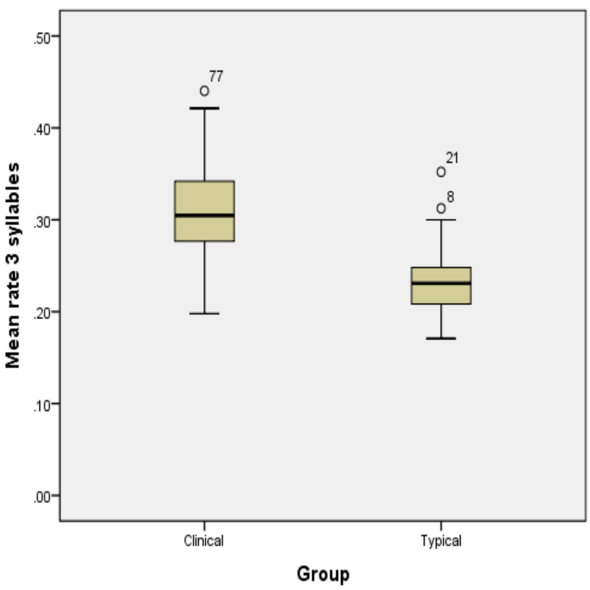


Figure 6.5 Combined mean rate for 3 syllable targets: comparison between clinical and typical groups.

6.4.4 Comparison between individual clinical children's rates and the typical group's mean rate by stimulus length

Each individual clinical child's DDK mean rate for 2 and 3 syllable targets was compared to the typical group's mean rates for 2 and 3 syllable targets (Mean .23, s.d. 0.5 and Mean .23, s.d. 0.4 respectively). Z scores and levels of significance were calculated. The rates for each clinical child are listed in Appendix 6.6 and the results are summarised in table 6.6.

Table 6.6 Comparison of individual clinical children's (n=40) DDK rate (seconds per syllable) with the typical group's mean DDK rates: summary of significance levels of z scores.

DDK Rate:	2 syllables	3 syllables
Missing data	1 (2.5%)	2 (5%)
Not significant	26 (65%)	17 (42.5%)
Any level of significance	13 (32.5%)	21 (52.5%)

For 2 syllable targets, thirteen clinical children (32.5%) produced significantly slower rates than the typical group, ten of whom produced rates which were highly significantly different (at $p<0.01$ or $p<0.001$ level). For 3 syllable targets, twenty-one children (52.5%) produced significantly slower rates than the typical children, and fourteen of these produced rates which were highly significantly different ($p<0.01$ or $p<0.001$).

Examination of the individual children's scores in Appendix 6.4, showed that two clinical children (IT5 and TC6) performed differently to the typical children at a highly significant level ($p<0.001$) for both 2 and 3 syllable targets. CS5's performance was also highly significantly slower ($p<0.001$) on 2 syllable targets (.53) but missing data prevented a calculation of his rate on 3 syllable targets. Four other children (MP4, SB4, IF5 and SC7) performed differently to the typical children on 3 syllable targets at a highly significant level ($p<0.001$), but with varying significance levels for 2 syllable targets: not significant for SB4; $p<0.05$ for MP4 and SC7; $p<0.01$ for IF5.

6.4.5 Summary of results for DDK rate by stimulus length

- As a group, the clinical children were slower than the typical children when producing both 2 and 3 syllable targets.

- Within the clinical group, the children produced 2 syllable targets faster than 3 syllable targets.
- Within the typical group, there was no difference in the children's rates for either 2 or 3 syllable targets.
- The clinical group's rates were affected by syllable length: around one third (32.5%) of the children produced 2 syllable targets at a slower rate compared to the typical group and this number increased to just over half (52.5%) on 3 syllable targets.

6.5 The number of repetitions produced

The DDK task required the children to repeat a target five times. However, some children stopped on some targets before the run of five repetitions was complete. This was therefore examined further to see how commonly it occurred in both the clinical and typical groups.

6.5.1 Clinical group: the number of repetitions produced

The number of repetitions produced by individual clinical children are listed in Appendix 6.7. There was missing data for two children (43 and 60) in some conditions and therefore mean scores for these children could not be calculated on full data.

The clinical children's group results by stimulus length (2 vs. 3 syllables) in each stimulus condition (RWs, NWs, SSs) and mean totals are presented in table 6.7.

Table 6.7 Clinical group (n=40): the number of repetitions produced for each stimulus length in each stimulus condition and the mean totals.

No. of Reps. /5:	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
Mean	4.94	4.69	4.88	4.84	4.85	4.74	4.89	4.77
s.d.	.12	.33	.19	.27	.27	.27	.12	.18
Median	5.00	4.75	5.00	5.00	5.00	4.75	4.92	4.83
Min.	4.50	4.00	4.25	4.00	4.00	4.00	4.58	4.25
Max.	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Key: No of reps=number of repetitions; RW2 =2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean number of repetitions for 2 syllable targets; Mean 3=mean number of repetitions for 3 syllable targets; s.d.= standard deviation; min=minimum; max=maximum.

There was variation within the group on the number of productions produced for both stimulus lengths in all stimulus conditions. However, the minimum score is not lower than 4 repetitions in any condition and the mean overall number of repetitions is 4.89 for 2 syllable targets and 4.77 for 3 syllable targets. Friedman ranks tests showed that although there was no significant difference in the number of repetitions produced across the conditions for 2 syllable targets (p=.311), there was a significant difference in the number of repetitions produced for 3 syllable targets (p<0.05). Post-hoc analyses using Wilcoxon signed ranks tests showed that more repetitions were produced in the NW (i.e. they stopped less frequently on NW targets) than in the RW (z=-2.407, p<0.05) or SS condition (z=-2.276, p<0.05), but there were no significant differences between the number of repetitions produced in the RW and SS conditions (z=-0.219, p=0.827).

6.5.2 Typical group: the number of repetitions produced

The number of repetitions produced by individual typical children's are listed in Appendix 6.8. There was missing data for one child (23) who did not complete the NW and SS conditions and therefore mean scores for this child could not be calculated on full data.

The typical group's results by stimulus length (2 vs. 3 syllables) in each stimulus condition (RWs, NWs, SSs) and mean totals are presented in table 6.8.

Table 6.8 Typical group (n=40): the number of repetitions produced on each stimulus length in each stimulus condition and the mean totals.

No.of reps. /5:	RW2	RW3	NW2	NW3	SS2	SS3	Means 2	Means 3
Mean	4.93	4.90	4.92	4.94	4.94	4.83	4.93	4.89
s.d	.16	.20	.16	.12	.12	.25	.10	.13
Median	5.00	5.00	5.00	5.00	5.00	5.00	4.92	4.92
Min	4.25	4.00	4.25	4.50	4.50	4.00	4.50	4.56
Max	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Key: No of reps=number of repetitions; RW2 =2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable, syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean number of repetitions for 2 syllable targets; Mean 3=mean number of repetitions for 3 syllable targets; s.d.= standard deviation; min=minimum; max=maximum.

There was variation within the group for both stimulus lengths in all stimulus conditions. However, the minimum score is not lower than 4 repetitions in any condition and the mean overall number of repetitions is 4.93 for 2 syllable targets and 4.89 for 3 syllable DDK targets.

For 2 syllable targets, a Friedman ranks test showed there were no significant differences (p=.896) in the number of repetitions produced across the conditions. This was also the case for 3 syllable targets (p=0.052). However, since this level was approaching significance, post-hoc analyses were carried out. These showed that significantly more (z=-2.746, p<0.01) repetitions were produced in the 3 syllable NW than in the 3 syllable SS condition. However, there were no significant differences in the number of repetitions of 3 syllable targets in the RW and NW conditions (z=-0.816, p=0.414) or the RW and SS conditions (z=-1.553, p=0.120).

6.5.3 Comparison of the number of repetitions produced by the clinical and typical groups

There was individual variation within both groups. A Mann-Whitney U test showed a significant difference between the clinical and typical groups in the mean number of repetitions of 3 syllable targets (z=-3.475, p<0.01) but not of 2 syllable targets (z=-1.303, p=0.192). Thus, the clinical children were more likely than the typical children to stop before the run of five repetitions of 3 syllable DDK targets was complete. These results are illustrated in figures 6.6 and 6.7.

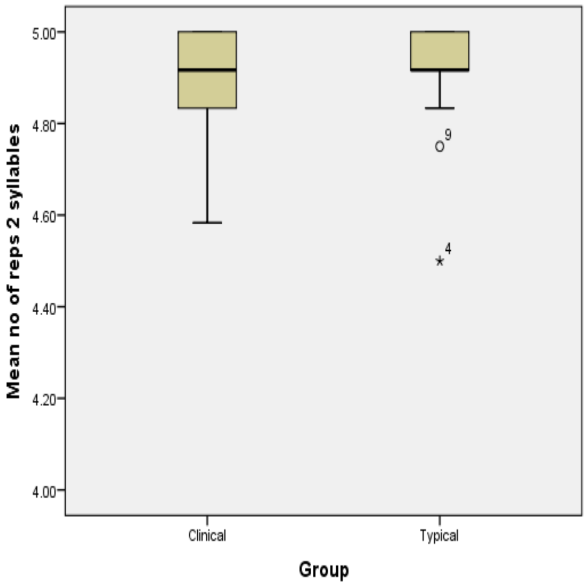


Figure 6.6 Comparison between the mean number of repetitions for 2 syllable targets across all conditions (RW, NW, SS), produced by the clinical and typical groups.

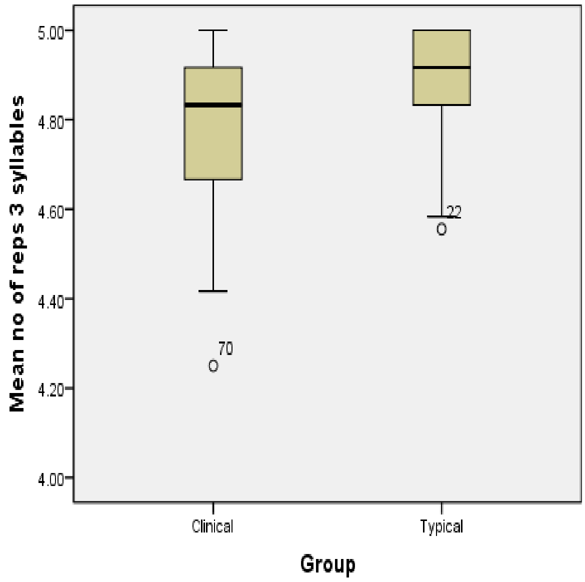


Figure 6.7 Comparison between the mean number of repetitions for 3 syllable targets across all conditions (RW, NW, SS), produced by the clinical and typical groups.

It should be noted that there were outliers in both groups who were more likely than other children in their group to stop before the run of five repetitions was complete. On 2 syllable targets, child 9 was an outlier and child 4 an extreme outlier in the typical group, but there were no outliers in the clinical group. On 3 syllable targets, there was one outlier in each group: child 22 in the typical group and child 70 in the clinical group. However, the mean scores of the outliers still fell between 4 and 5 repetitions.

6.5.5 Summary of results for number of repetitions

- The minimum number of repetitions produced by both the clinical and typical groups was 4/5 on both 2 and 3 syllable targets, across all the stimulus conditions.
- The clinical group performed similarly to the typical group on 2 syllable targets, but on 3 syllable targets they stopped before the run of five repetitions was complete more often than the typical group.

6.6 Summary of main results for rate

As a group, the clinical group were significantly slower than the typical group in each of the stimulus conditions (RWs, NWs, SSs) and on mean rate, across the conditions. Both the clinical and typical groups produced slower rates on NW targets. As a group, the clinical children were significantly slower than the typical children when producing both 2 and 3 syllable targets. The clinical children produced 2 syllable targets faster than 3 syllable targets, whereas the typical children produced 2 syllable targets at the same rate as 3 syllable targets. The clinical children stopped before the run of five repetitions was complete on 3 syllable targets more often than the typical children. There was individual variation within the clinical group and only half of the individual clinical children could be differentiated from the typical children on DDK mean rate. Some individual clinical children produced much slower rates in comparison to the typical group, and this could not be accounted for by age and maturity alone.

Chapter Seven

Results IV:

DDK Accuracy in relation to DDK Consistency and DDK Rate

7.1 Research questions

The following research questions will be considered in this chapter:

(a) Is there a relationship between DDK accuracy and DDK consistency for the clinical and typical children as groups?
(b) Is there a relationship between DDK accuracy and DDK rate for the clinical and typical children as groups?
(c) Is it possible to identify individual DDK profiles based on accuracy, consistency and rate within the clinical group, in comparison to age-matched typically-developing children?

In chapters four, five and six, the performance of the clinical and typical children have been examined on separate measures of DDK accuracy, DDK consistency and DDK rate. In this chapter, the relationships between these measures will be considered. It should be noted that DDK consistency cannot be considered as a variable independent of DDK accuracy, since to be accurate a child by definition must also be consistent (e.g. children who were accurate on five repetitions had consistently produced them in the same way). However, children who were inaccurate might or might not be inconsistent, depending on whether they produced five same repetitions or two or more different repetitions in comparison to their baseline production.

7.2 DDK Accuracy and DDK Consistency

7.2.1 Clinical children as a group: differences in performance on DDK accuracy and DDK consistency

Individual children's total mean scores (binary /24) across the stimulus conditions (RW, NW and SS) for accuracy and consistency of five repetitions are listed in appendices 4.6 and 5.1.

The individual children's mean scores were combined to produce the clinical group results which are presented in table 7.1. There was missing data for one child (43) who did not co-operate for the SS condition and therefore total mean scores were calculated on 39 rather than 40 children.

Table 7.1 Clinical group (n=39): Mean accuracy and consistency scores (binary /24) for five repetitions.

	Acc x 5 totals /24	Consist x 5 totals /24
Mean	11.08	14.95
s.d.	6.50	4.62
Median	11.00	14.00
Minimum	1.00	2.00
Maximum	23.00	23.00

Key: Acc x 5=accuracy of five repetitions; Consist x 5 =consistency of 5 repetitions; s.d.=standard deviation.

A Wilcoxon signed ranks test, showed there was a highly significant difference between the two measures ($z=-4.464$, $p<0.001$): as a group the clinical children scored more highly on consistency than accuracy. Examination of the Wilcoxon ranks, revealed that two-thirds (n=26) of the children scored more highly on consistency than accuracy, whilst one third (n=13) scored similarly on accuracy and consistency.

7.2.2 Clinical children as a group: relationship between DDK accuracy and DDK consistency

The relationship between the mean total DDK accuracy scores and the mean total DDK consistency scores (binary /24) of five repetitions was examined for the clinical children using non-parametric correlational analyses (Spearman's rho). A significant positive correlation (.703, $p<0.01$) was found for the clinical group and this effect was large (see figure 7.1).

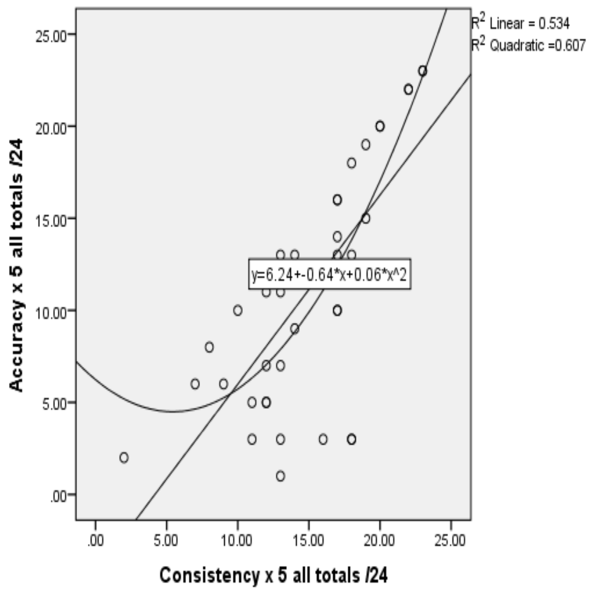


Figure 7.1 Clinical group (n=39): relationship between total DDK accuracy and total DDK consistency scores (binary /24).

A further correlation was run to compare DDK accuracy scores, when scored by mean PCC, and mean total DDK consistency scores (binary /24). A similar result was obtained for the clinical children (.594, $p<0.01$). Therefore, for the clinical children as a group, it was concluded there was a strong positive relationship between their DDK accuracy and DDK consistency scores, which was not unexpected as the two variables are not totally independent.

7.2.3 Typical children as a group: differences in performance on DDK accuracy and DDK consistency

Individual children's total mean scores (binary /24) across the stimulus conditions (RW, NW and SS) for accuracy and consistency of five repetitions are listed in appendices 4.8 and 5.2.

The individual children's mean scores were combined to produce the typical group results which are presented in table 7.2. There was missing data for one child (23) who did not complete the NW and SS conditions and therefore total mean scores were again calculated on 39 rather than 40 children.

Table 7.2 Typical group (n=39): Mean accuracy and consistency scores (binary /24) for five repetitions.

	Acc x 5 totals /24	Consist x 5 totals /24
Mean	19.13	19.46
s.d.	2.75	2.39
Median	19.00	19.00
Minimum	13.00	14.00
Maximum	23.00	23.00

Key: Acc x 5=accuracy of five repetitions; Consist x 5 =consistency of 5 repetitions; s.d.=standard deviation.

A Wilcoxon signed ranks test, showed there was a significant difference between the two measures ($z=-2.389$, $p<0.05$): as a group the typical children scored more highly on consistency than accuracy. Examination of the Wilcoxon ranks revealed that just over two-thirds (n=27) of the typical children scored similarly on accuracy and consistency. Of the remaining third, ten scored more highly on consistency than accuracy and two scored more highly on accuracy than consistency.

7.2.4 Typical children as a group: relationship between DDK accuracy and DDK consistency

The relationship between the mean total DDK accuracy scores and the mean total DDK consistency scores (binary /24) of five repetitions was examined for the typical children using non-parametric correlational analyses (Spearman's rho). A significant positive correlation (.966, $p<0.01$) was found for the typical group and this effect was also large (see figure 7.2).

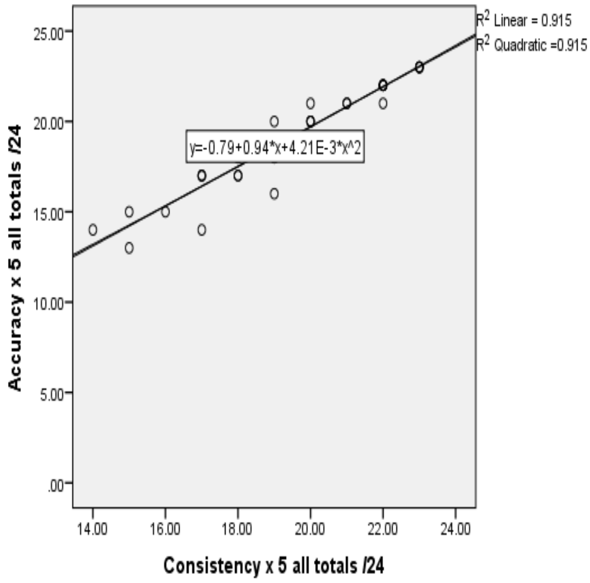


Figure 7.2 Typical group (n=39): relationship between total DDK accuracy and total DDK consistency scores (binary /24).

A further correlation was run to compare DDK accuracy scores, when scored by mean PCC, and mean total DDK consistency scores (binary /24). A similar result was obtained for the typical children (.685, p<0.01). Therefore, for the typical children as a group, it was concluded there was a strong positive relationship between their DDK accuracy and DDK consistency scores, which was not unexpected as the two variables are not totally independent.

7.2.5 Comparison between clinical and typical groups on DDK accuracy and DDK consistency

As a group, the clinical children produced significantly lower DDK accuracy and DDK consistency scores than the typical children (mean 11.08 vs. 19.13 for DDK accuracy and mean 14.95 vs. 19.46 for DDK consistency –see tables 7.1 and 7.2). Furthermore, the clinical children as a group demonstrated a greater differential between their mean total accuracy and consistency scores than the typical children (clinical children: p<0.001 level cf. typical children p<0.05 level). They also showed more evidence of individual variation than the typical group for both DDK accuracy and DDK consistency (see minimum and maximum scores in tables 7.1 and 7.2).

7.2.6 Comparison between individual clinical children and the typical group on DDK accuracy and DDK consistency

The mean total scores (binary /24) of each individual clinical child were compared to the typical group's mean total scores for DDK accuracy (mean 19.13, s.d. 2.75) and DDK consistency (mean 19.46, s.d. 2.39). Appendix 7.1 details the z scores and levels of significance for the individual children and the results are summarised in table 7.3.

Table 7.3 Individual clinical children's scores (n=40) on DDK accuracy and DDK consistency in comparison to the typical group's mean scores: summary of significance levels for z scores.

	No. of clinical children N=40
Missing	1 (2.5%)
Not significant	11 (27.5%)
Inaccurate but consistent	8 (20%)
Inaccurate and inconsistent	20 (50%)
Total N	40 (100%)

Key: z= +/- 1.65 is significant at $p<0.05$ level; z=+/-2.33 is significant at $p<0.01$ level; z=+/-3.29 is significant at $p<0.001$ level.

For eleven clinical children (27.5%), the nature of their specific speech difficulties did not affect their DDK accuracy or DDK consistency and they performed no differently to the typical children. Eight clinical children (20%) performed similarly to the typical children on consistency but more poorly on accuracy (described as inaccurate but consistent in table 7.3). Twenty clinical children (50%) performed more poorly than the typical group on both accuracy and consistency (described as inaccurate and inconsistent in table 7.3).

It was concluded that there was no group pattern of performance amongst the clinical children. Instead, there was some evidence of subgrouping with children showing differing patterns of performance when DDK accuracy and DDK consistency scores were examined together.

7.2.7 Summary of main findings for DDK accuracy and DDK consistency

- A strong positive relationship between DDK accuracy and DDK consistency was found for both the clinical and typical groups.
- As a group, the clinical children were less accurate and less consistent than the typical group (both at a $p<0.001$ level).
- Within the clinical group, half of the children (50%) scored more poorly than the typical group on both DDK accuracy and DDK consistency.
- Within the clinical group, eight children (20%) were as consistent as the typical group on the DDK tasks, even though they were less accurate.

- Within the clinical group, eleven children (just under 30%) scored no differently to the typical group on DDK accuracy and DDK consistency.

7.3 DDK Accuracy and DDK Rate

7.3.1 Clinical children as a group: relationship between DDK accuracy and DDK rate

Individual children's total mean scores (binary /24) across the stimulus conditions (RW, NW and SS) for accuracy of five repetitions are listed in appendix 4.6 and DDK mean rates are listed in appendix 6.1.

The individual children's mean scores were combined to produce the clinical group results which are presented in table 7.4. There was missing data for one child (43) who did not co-operate for the SS condition and therefore total mean scores for accuracy and rate were calculated on 39 rather than 40 children.

Table 7.4 Clinical group (n=39): Mean DDK accuracy scores (binary /24) and DDK mean rates (in seconds) for five repetitions.

	Acc x 5 totals /24	Mean rate per syllable
Mean	11.08	.31
s.d.	6.50	.07
Median	11.00	.29
Minimum	1.00	.19
Maximum	23.00	.55

Key: Acc x 5 = accuracy of five repetitions; s.d.=standard deviation.

The relationship between DDK accuracy and DDK rate was examined for the clinical children using non-parametric correlational analyses (Spearman's rho). There was no significant correlation between the mean total DDK accuracy scores (binary /24) of five repetitions and mean DDK rate in seconds per syllable (-.094, p=0.571) in the clinical group. This was also the case when the DDK mean rates were sub-divided into rates for 2 syllable (-.087, p=0.600), and 3 syllable (.001, p=0.994) targets. Further correlations were run to compare mean DDK accuracy scores (PCC), and DDK mean rates. Again, no significant correlations were found between DDK accuracy and DDK rate.

It had been hypothesised that there would be a relationship between DDK accuracy and DDK rate. In particular, children in the clinical group might have been slowing their rate of production, in an attempt to maintain accuracy. However, this hypothesis was not supported by the findings - there was no clear evidence of a relationship between DDK accuracy and DDK rate in the clinical group.

7.3.2 Typical children as a group: relationship between DDK accuracy and DDK rate

Individual children's total mean scores (binary /24) across the stimulus conditions (RW, NW and SS) for accuracy of five repetitions are listed in appendix 4.8 and DDK mean rates are listed in appendix 6.2 . There was missing data for one child (23) who did not complete the NW and SS conditions and therefore total mean scores for accuracy and rate were again calculated on 39 rather than 40 children.

The individual children's mean scores were combined to produce the typical group results which are presented in table 7.5.

Table 7.5 Typical group (n=39): Mean DDK accuracy scores (binary /24) and DDK mean rates (in seconds) for five repetitions.

	Acc x 5 totals /24	Mean rate per syllable
Mean	19.13	.23
s.d.	2.75	.04
Median	19.00	.24
Minimum	13.00	.17
Maximum	23.00	.34

Key: Accuracy x 5 = accuracy of five repetitions; s.d.=standard deviation.

Correlational analyses (Spearman's rho) showed no significant correlation between DDK accuracy scores (binary /24) and DDK mean rate in seconds per syllable (-.026, p=0.571) for the typical children. The same was found when the DDK mean rate score was sub-divided into rates for 2 syllable (.018, p=0.915), and 3 syllable (-.100, p=0.544) targets. Further correlations were also run to compare DDK mean accuracy scores (PCC), and DDK mean rate scores. Again there were no significant correlations between DDK accuracy and DDK rate. Therefore, for the typical children as a group, there was no clear relationship between DDK accuracy and DDK rate.

7.3.3 Comparison between clinical and typical groups on DDK accuracy and DDK rate

As a group, the clinical children produced significantly lower DDK accuracy scores and significantly slower DDK mean rates, than the typical children. The clinical children also showed more evidence of individual variation than the typical group for both DDK accuracy and DDK rate (see minimum and maximum scores in tables 7.4 and 7.5).

7.3.4 Comparison between individual clinical children and the typical group on DDK accuracy and DDK rate

The mean total accuracy scores (binary /24) and the DDK mean rates of each individual clinical child were compared to the typical group's mean total scores for accuracy (mean 19.13, s.d. 2.75) and mean rate (mean .23, s.d. .04). Appendix 7.2 details the z scores and levels of significance for the individual children and the results are summarised in table 7.6.

Table 7.6 Individual clinical children's scores (n=40) on DDK accuracy and DDK rate in comparison to typical group's mean scores: summary of significance levels for z scores.

	No. of clinical children (n=40)
Missing	1 (2.5%)
Not significant	7 (17.5%)
Inaccurate only	13 (32.5%)
Slower rate only	4 (10%)
Inaccurate & slower rate	15 (37.5%)
Total	40 (100%)

For seven of the clinical children (17.5%), the nature of their specific speech difficulties did not affect their DDK accuracy or DDK rate and they performed no differently to the typical children. Thirteen children (32.5%) performed more poorly than the typical children on DDK accuracy but not on DDK rate (described as inaccurate only in table 7.6), whilst four children

(10%) performed more poorly than the typical children on DDK rate but not on DDK accuracy (described as slower rate only in table 7.6). The remaining fifteen clinical children (37.5%) performed more poorly than the typical group on both DDK accuracy and DDK rate (described as inaccurate and slower rate in table 7.6).

It was concluded that there was no group pattern of performance within the clinical children. Instead, there was some evidence of subgrouping with individual children showing differing patterns of performance when DDK accuracy and DDK rate scores were examined together.

7.3.5 Summary of main findings for DDK accuracy and DDK rate

- There was no significant relationship between DDK accuracy and DDK rate for either the clinical or typical groups. Thus, there was no evidence of a speed-accuracy trade off.
- The clinical group as a whole were significantly less accurate and were significantly slower than the typical group ($p<0.001$ for both).
- Within the clinical group, fifteen children (37.5%) performed more poorly than the typical group on both DDK accuracy and DDK rate.
- Within the clinical group, thirteen children (32.5%) performed more poorly than the typical group on DDK accuracy but not DDK rate.
- Within the clinical group, four children (10%) performed more poorly than the typical group on DDK rate, but not on DDK accuracy.

7.4 DDK Accuracy in relation to DDK Consistency and DDK Rate

The results for the clinical children as a group in comparison to age matched typically-developing children have shown that:

- 29/40 children (72.5%) had a difficulty with DDK accuracy, either in isolation or in combination with DDK consistency and/or in combination with DDK rate.
- 20/40 children (50%) had a difficulty with DDK rate, either in isolation or in combination with DDK accuracy or in combination with DDK accuracy and DDK consistency.
- 21/40 children (52.5%) had a difficulty with DDK consistency, either in combination with DDK accuracy or in combination with DDK accuracy and DDK rate.
- 7/40 children (17.5%) performed no differently to age matched typically-developing children on DDK accuracy, DDK consistency or DDK rate.

It should be noted that the above figures include EW4, who did not complete all subtests and is recorded as missing in tables 7.3 and 7.5. However, based on what she did complete, she demonstrated significant difficulties on DDK accuracy, DDK consistency and DDK rate.

7.5 Individual DDK profiles

On the basis of above group results, six distinct DDK profiles emerged within the clinical group: 1) DDK inaccuracy only, 2) DDK inaccuracy and DDK inconsistency, 3) DDK slower rate only, 4) DDK inaccuracy and DDK slower rate, 5) DDK inaccuracy, DDK inconsistency and DDK slower rate, and 6) no difficulties on any DDK measure compared to age-matched controls (see table 7.7 for DDK profiles and 7.8 for details of individual children who fell into each DDK profile). A full list of the children's profiles can be found in Appendix 7.3.

Table 7.7 DDK profiles based on clinical group results when compared to age matched controls.

No.	DDK Profile	Accuracy	Consistency	Rate
1.	Inaccurate only	X	√	√
2.	Inaccurate and inconsistent	X	X	√
3.	Slower rate only	√	√	X
4.	Inaccurate and slower rate	X	√	X
5.	Inaccurate, inconsistent and slower rate	X	X	X
6.	No significant difficulties	√	√	√

Key: X=difficulty; √=no difficult.

Table 7.8 Clinical children (n=40): Individual DDK profiles.

DDK Profiles	Individual children, by identifying code.	No. of children	% total
1. DDK Inaccuracy only	DC4, PG4, DG5, TM6	4	10
2. DDK Inaccuracy & DDK Inconsistency	LR4, TB4, JK5, KK5, OP5, RH5, AG6, CC6 HL6	9	22.5
3. DDK Slower rate only	IF5, RB5, JC7, SC7	4	10
4. DDK Inaccuracy & DDK slower rate	MP4, TH4, IT5, TC6	4	10

5. DDK Inaccuracy, DDK Inconsistency & DDK slower rate	AJ4, JJ4, SB4, CS5, EN5, JB5, KW5, LS5, OB5, TN5, EC6 & (EW4)	12	30
6. No significant DDK difficulties	ChS5, JC5, PBS5, RW5, SH5, HM6, KH6	7	17.5
Totals		40	100

NB EW4 did not complete all subtests, but on tasks she did complete, she showed significant difficulties with DDK accuracy, DDK consistency and DDK rate.

DDK Profile 1: DDK Inaccuracy only (n=4)

On the DDK tasks, four children (DC4, PG4, DG5, TM6,) performed no differently to the age-matched typically-developing children on DDK rate or DDK consistency, but scored significantly less well on DDK accuracy (scored by both binary and PCC methods) – DC4, PG4 and TM6 at a $p<0.001$ significance level and DG5 at a $p<0.05$ significance level.

DDK Profile 2: DDK Inaccuracy and DDK Inconsistency (n=9)

On the DDK tasks, nine children (LR4, TB4, JK5, KK5, OP5, RH5, AG6, CC6, HL6) performed no differently to the age matched typically-developing children on DDK rate, but scored significantly less well on DDK accuracy and DDK consistency. On DDK accuracy, eight children (LR4, TB4, JK5, KK5, OP5, RH5, AG6, HL6) scored differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$) and one child (CC6) scored differently at a $p<0.05$ significance level. On DDK consistency, seven children (LR4, JK5, KK5, OP5 RH5, AG6, HL6) scored differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$) and two children (TB4, CC6) scored differently at a $p<0.05$ significance level.

DDK Profile 3: DDK Slower rate only (n=4)

On the DDK tasks, four children (IF5, RB5, JC7, SC7) performed no differently to the age matched typically-developing children on DDK accuracy or DDK consistency, but scored significantly less well on DDK rate – RB5, JC7 and SC7 at a $p<0.01$ significance level and IF5 at a $p<0.001$ significance level.

DDK Profile 4: DDK Inaccuracy and DDK Slower rate (n=4)

On DDK tasks, four children (MP4, TH4, IT5, TC6) scored no differently to age-matched typically-developing children on DDK consistency, but scored significantly less well on DDK accuracy and DDK rate. On DDK accuracy, two children (TH4, IT5) scored differently to the controls at a $p<0.001$ significance level and two children (MP4, TC6) scored differently at a $p<0.05$ significance level. On DDK rate, all four children scored significantly differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$).

DDK Profile 5: DDK Inaccuracy, DDK Inconsistency and DDK Slower rate (n=12)

On DDK tasks, twelve children (AJ4, JJ4, SB4, EW4, CS5, EN5, JB5, KW5, LS5, OB5, TN5, EC6) scored significantly less well than age-matched typically-developing children on DDK accuracy, DDK consistency and DDK rate. On DDK accuracy, all the children scored differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$), with the exception of EN5 who scored differently at a $p<0.05$ significance level. On DDK consistency, all the children scored differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$), with the exception of JB5 who scored differently at a $p<0.05$ significance level. On DDK Rate, four children (JJ4, CS5, LS5, EC6) scored differently to the controls at a highly significant level ($p<0.01$ or $p<0.001$) and seven children (AJ4, SB4, EN5, JB5, KW5, OB5, TN5) scored differently at a $p<0.05$ significance level. NB EW4 did not complete all subtests, but has been included in this DDK Profile since she showed significant difficulties with DDK accuracy, DDK consistency and DDK rate on those tasks she did complete. However, it has not been possible to identify significance levels as for the other children, as these were derived from mean results.

DDK Profile 6: No significant DDK difficulties (n=7)

On DDK tasks, seven children (ChS5, JC5, PBS5, RW5, SH5, HM6, KH6) scored no differently to age matched typically-developing children on DDK accuracy, DDK consistency or DDK rate.

7.6 Summary of main findings

A strong positive relationship between DDK accuracy and DDK consistency was found for both the clinical and typical groups. To some extent this was expected, as children who were accurate had to be consistent due to the scoring method employed. However, within the clinical group, half the children were both inaccurate and inconsistent. Although there was individual variation, the clinical children as a group were both significantly less accurate and significantly less consistent than the typical children as a group. By contrast, no significant relationship between DDK accuracy and DDK rate was found for either the clinical or typical children as groups. Thus, a possible trade off between accuracy and rate whereby children slow their rate to maintain accuracy was not found in either the clinical or typical groups. Although there was individual variation, the clinical group as a whole were both significantly less accurate and significantly slower than the typical group. However, the clinical children did not perform as a homogeneous group. When the clinical children's individual results on DDK accuracy, DDK consistency and DDK rate were compared to the typical group's mean results, six distinct DDK profiles emerged.

Chapter Eight

Results: V

Clinical children: relationships between DDK and performance on other speech processing measures

8.1 Introduction

In order to have an overview of the clinical children's speech processing skills, they were assessed on a range of tasks in addition to DDK tasks. These were: (1) a mispronunciation detection task to assess accuracy of lexical representations; (2) an oro-motor assessment task to assess oral skills; (3) a single consonant sound imitation task to assess phonetic accuracy of isolated consonant sounds; (4) a single word naming task to assess consonant sound accuracy in words; (5) a single word naming task repeated three times to assess lexical consistency; and (6) a picture description task to assess connected speech rate. Details of all these tasks are provided in Chapter Three: Method.

8.2 Research questions

The following research questions will be considered in this chapter:

1. For the clinical group, is there a relationship between (a) DDK accuracy, (b) DDK consistency and (c) DDK rate and the following measures?
    - accuracy of lexical representations
    - oral motor skills
    - accuracy of single consonant sounds
    - accuracy of single word naming
    - consistency of single word naming
    - connected speech rate

2. For the children with speech difficulties as individuals: can the children be divided into distinct subgroups, when their individual DDK profile is combined with their performance on other measures?

Note on DDK Accuracy: Since the overall results from accuracy of five repetitions were similar, whether the binary or PCC scoring method was used, it was decided to use the scoring method which was the ‘best fit’ for the relationship being investigated. PCC was used in comparisons with percentage scores and binary scores in comparisons with raw scores, where possible.

8.3 Accuracy of Lexical Representations

An auditory lexical discrimination task was devised specifically for the study utilising the real word targets of the DDK tasks (see Chapter Three, 3.5.4, for further detail). This mispronunciation detection test (MDT) was presented through SIPc software (Vance et al., 2009), which also calculated scores (/60) objectively. Since a few children were unable to complete all four blocks of test items, raw scores were converted to percentage scores for the analyses.

Data was also collected from typical children, in order to provide age-matched comparisons for the clinical children’s scores on this non-standardized task.

8.3.1 Comparison between results from clinical and typical children

A full list of raw scores and percentage scores for the individual clinical and typical children are presented in Appendix 8.1. Table 8.1 presents the descriptive statistics for the clinical group and table 8.2 for the typical group.

Table 8.1 Clinical children (N =40): percentage scores on the mispronunciation detection task.

	Percentage score
Mean	90.30
s.d.	8.75
Median	93.00
Minimum	60.00
Maximum	100.00

Key: s.d. = standard deviation

Table 8.2 Typical children (N=40): percentage scores on the mispronunciation detection task.

	Percentage Score
Mean	93.68
s.d.	8.58
Median	95.00
Minimum	50.00
Maximum	100.00

Key: s.d. = standard deviation.

There was individual variation in both the clinical and typical groups, but more so in the clinical group. When the mean percentage group scores of the clinical children were compared to those of the typical children, a significant difference was found (z=-2.394, $p<0.05$) –see figure 8.1.

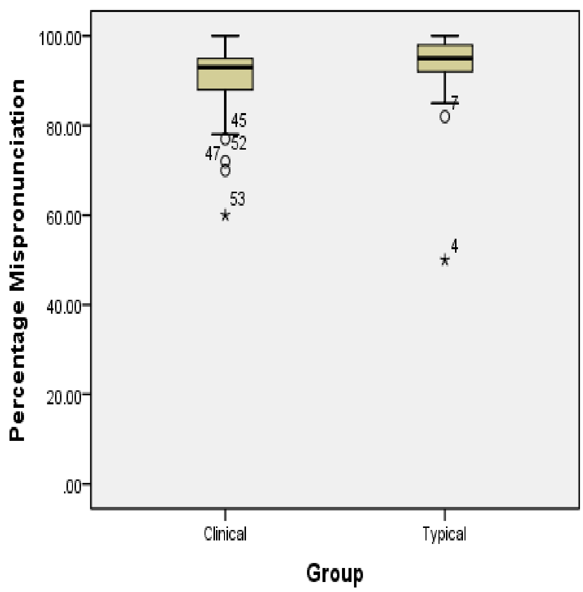


Figure 8.1 Comparison between the mean percentage scores of the clinical and typical groups on a mispronunciation detection task.

As a group, the typical children obtained a higher mean and median score than the clinical children and there was less individual variation in scores. There were a small number of outliers in both groups: Children 7 and 4 in the typical group and Children 45, 47, 52, 53 in the clinical group. Despite the differences in scores, both groups overall, scored a percentage median score of over 92% and a percentage mean score of over 90%.

8.3.2 Comparison between clinical and typical children's errors on the MDT

Each child's errors (N/60) made on the MDT were recorded by stimulus length (2 vs. 3 syllables) and error type in five categories: rejection of correct target, consonant perseveration mispronunciations, consonant transposition mispronunciations, other consonant mispronunciations (manner or voice mispronunciations) and vowel mispronunciations. Definitions and examples of each of these are provided in Chapter Three, 3.7.2. The individual scores produced by each child were added together to produce detection error counts for the clinical and typical groups (see table 8.3).

Table 8.3 Comparison of clinical and typical children's errors by stimulus length and mispronunciation type.

Mispronunciation type	**Clinical group (n=40)**	**Typical group (n=40)**
N/60 included in task:	No. of errors made by all children /totals possible for each error type.	No. of errors made by all children /totals possible for each error type.
Rejection of correct target 2 syllables (12/60 targets)	44 / 480	29 / 480
Rejection of correct target 3 syllables (8/60 targets)	30 / 320	20 / 320
Rejection of correct target Totals (20/60 targets)	74 / 800	49 / 800
Consonant perseveration 2 syllables (4/60 targets)	7 / 160	10 / 160
Consonant perseveration 3 syllables (8/60 targets)	57 / 320	22 / 320
Consonant perseveration Totals (12/60 targets)	64 / 480	32 / 480
Consonant transpositions 2 syllables (4/60 targets)	10 / 160	6 /160
Consonant transpositions	24 / 160	20 / 160

3 syllables (4/60 targets)		
Consonant transpositions Totals (8/60)	34 / 320	26 / 160
Other 2 syllable consonant mispronunciations (8/60 targets)	20 / 320	30 / 320
Other 3 syllable consonant mispronunciations (0/60 targets) (i.e. no examples included in task)	0 /0	0 / 0
Other 2 & 3 syllable consonant mispronunciations Totals (8/60 targets)	20 / 320	30 / 320
Vowel mispronunciations 2 syllables (4/60 targets)	10 / 160	9 / 320
Vowel mispronunciations 3 syllables (8/60 targets)	27 / 320	18 / 320
Vowel mispronunciations totals (12/60 targets)	37 / 480	27 / 480
Total no. of detection errors made	229 /2400	164 /2400

As a group, the clinical children made more errors overall (n=229) than the typical children (n=164), and one child in the typical group (Child 4) was responsible for 30 of the total number of errors. Furthermore, the clinical children made more errors than the typical children on most mispronunciation types, other than on 2 syllable consonant perseverations and other 2 syllable consonant mispronunciations where the typical children made more errors.

8.3.3 Comparison between individual clinical children's scores and the typical group mean scores

Each clinical child's percentage correct score on the MDT was compared to the typical group mean scores and z scores and significance levels were calculated. A full list of these results is given in Appendix 8.2 and the results are summarised in table 8.4.

Table 8.4 Clinical children's (n=40) MDT individual scores compared to typical children's group mean scores

	No. of children (/40)
Not significant	35 (87.5%)
Any level of significance	5 (12.5%)
Total	40 (100%)

The results showed that the majority (87.5%) of clinical children scored no differently to the typical children on the MDT task. Only five children (LR4, PG4, CS5, DG5, RH5) scored significantly differently to the typical group children, three of these (PG4, CS5 and DG5) at a highly significant level ($p<0.01$ or $p<0.001$). Examination of the individual children's scores revealed that four children (LR4, PG4, CS5 & RH5) scored 47/60 correct or less and DG5 scored particularly poorly with only 37/60 correct. These five children made eighty-five errors between them, which accounted for almost 40% of the total errors (n=229) made by the forty clinical children. There was no clearly defined pattern to the children's errors –each of the five made errors in each mispronunciation type and on both 2 and 3 syllable targets.

8.3.4 Relationship between DDK and Lexical Representations in the Clinical Group

8.3.4.1 DDK Accuracy and Accuracy of lexical representations

Correlational analyses were carried out to examine the relationship between DDK accuracy (mean PCC, across the RW, NW and SS stimulus conditions) and percentage scores correct on the MDT for the clinical children. A strong positive relationship was found (.574, $p<0.01$) - see figure 8.2. Since MDT is a test of accuracy of lexical representations, further correlational analyses were run to see if there was a difference in the relationship between MDT and DDK accuracy on RWs, NWs and SSs. The results showed a strong positive relationship between MDT and both novel targets (NWs .569 and SSs .457, both at $p<0.01$) as well as RW targets (.558, $p<0.01$).

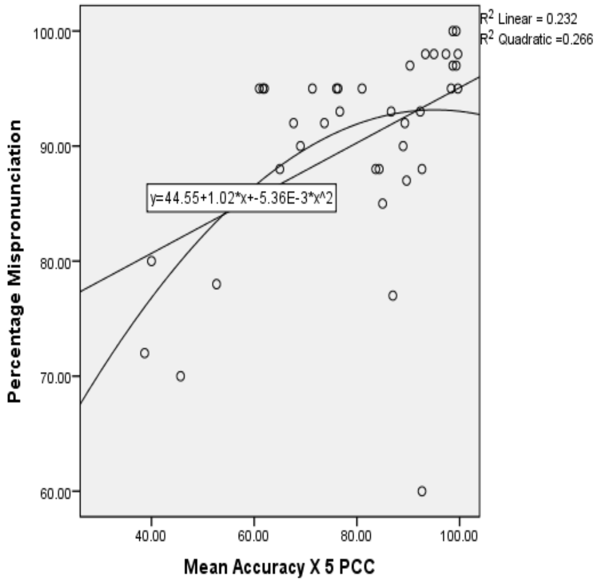


Figure 8.2 Clinical children (n=40): Relationship between DDK accuracy (mean PCC), and percentage correct scores on a mispronunciation detection task.

For the clinical children as a group, DDK Accuracy was found to have a strong positive relationship with accuracy of lexical representations. However, this was true for both RWs, which have a lexical representation, and NWs and SSs, which do not. It seems possible that because the NW DDK targets in this study are similar to the RW targets in terms of stress patterning as well as syllable structure, the children treated both targets the same. However, this would not explain why similar strong correlations were also found on the SS targets, where the stress pattern is different. An alternative interpretation could be that the children assumed they were being asked to repeat verbal targets and therefore did as asked, without making any distinction between the stimulus type. In particular, the rhythmic nature of the DDK task may have reinforced to the children that they were being asked to repeat linguistic targets.

All five individual clinical children (LR4, PG4, CS5, DG5, RH5) who scored significantly differently to the typical group children on the MDT, also had significant difficulties with DDK accuracy, when compared to the typical group.

8.3.4.2 DDK Consistency and Accuracy of lexical representations

Correlational analyses were carried out to examine the relationship between DDK consistency (binary) and percentage scores correct on the MDT for the clinical children. A weak, positive relationship (.367, $p<0.05$, weak) was found. Of the five individual clinical children (see 8.3.3) who scored significantly differently to the typical group children on the MDT, three (LR4, CS5 &

RH5) had significant difficulties with DDK consistency, as well as DDK accuracy, when compared to the typical group.

8.3.4.3 DDK Rate and Accuracy of lexical representations

Correlational analyses were carried out to examine the relationship between DDK rate (mean rate in seconds per syllable) and percentage scores correct on the MDT for the clinical children. No significant relationship (-.073, p=0.657, ns) was found. Of the five individual clinical children (see above) who scored significantly differently to the typical group children on the MDT, only one of these children (CS5) had significant difficulties with DDK rate. It seems likely that this child has severe and pervasive difficulties which affect his speech processing skills at all levels on both input and output tasks.

8.4 Oral motor skills

The clinical children were assessed on two subtests of the Oro-motor assessment from the *Diagnostic Evaluation of Articulation and Phonology* (Dodd et al., 2002): (a) isolated movements (IM) and (b) sequenced movements (SM). Examples of tasks are given in Chapter Three, 3.5.5 and scoring information in 3.7.3). Raw scores, standard scores and percentiles are presented in Appendix 8.3. One child (EC6) was not co-operative on all test items and therefore a total raw score could not be calculated for either IM or SM. Therefore, table 8.4 presents the descriptive statistics of 39 children's raw scores.

Table 8.4 Clinical children (n=39): raw scores on Isolated movements (IM) and Sequenced Movements(SM) from the DEAP Oro-motor Assessment.

	IM raw score /12	SM raw score /18
Mean	10.00	15.74
s.d.	1.36	1.90
Median	10.00	16.00
Minimum	7.00	11.00
Maximum	12.00	18.00

Key: IM =Isolated movements; SM =Sequenced movements; s.d. =standard deviation.

There was individual variation on both tasks, but the group mean and median scores were high for both IM (10/12 and 10/12 respectively) and SM (15.74/18 and 16/18 respectively). Table 8.5 presents a summary of the children's individual scores in comparison to standard scores for age.

Table 8.5 Clinical children (n=39): performance on IM and SM of DEAP Oro-motor assessment in comparison to standard scores.

No. of children (n=40)	Isolated movements (IM)	Sequenced movements (SM)
Within normal range	25 (62.5%)	34 (85%)
Below normal range	12 (30%)	3 (7.5%)
Outside age range of test	2* (5%)	2* (5%)
Did not co-operate	1 (2.5%)	1 (2.5%)
Total no.	40 (100%)	40 (100%)

Key: within normal range (standard scores 7-13): *= although these two children were outside the age range of the test, neither scored at maximum on either subtest (JC7 scored: 8/12 on IMs and 15/18 on SMs; SC7 scored 11/12 on IMs and 16/18 on SMs) and therefore presented with some oral motor difficulties.

As a group, the clinical children scored better on SM than on IM, and this difference was highly significant (z=-3000, p<0.01). Only 7.5% of the clinical children scored below the normal range on SMs, whereas 30% scored below the normal range on IMs. This result was unexpected since it is more usual for children to experience difficulties on sequenced movements where two movements have to be combined than on isolated single movements. However, this result may be explained by the particular oral movements included in the two subtests. Three of the six movements in SM (kiss, cough and yawn) are not included in IM. Furthermore, children may have more everyday experience of these three oral movements than the tongue and lip movements included in the IM. It is also noteworthy that in the DEAP manual, two of the individual case study children, Joshua, 4;5 years (p.53) and Natalie, 6;8 years (p.57), also scored better on SM than IM. It therefore appears that the IM subtest of the DEAP may be a more robust measure of oral motor competence than the SM subtest.

8.4.1 DDK Accuracy and Oral motor skills

Correlational analyses were carried out to examine the relationship between DDK accuracy (binary) and raw scores for IM and SM for the clinical children (see table 8.6).

Table 8.6 Clinical children: Correlations (Spearman's rho) between DDK accuracy (binary) and raw scores for Isolated Movements (IM) and Sequenced Movements (SM).

	IM	SM
DDK Accuracy (binary /24)	.078, p=0.644, ns.	0.32, p=0.848, ns.

Key: ns=not significant.

There was no significant relationship between DDK accuracy (binary) and raw scores on Oro-motor subtests, whether involving isolated (single) movements or sequenced (combination of two) movements. Despite this overall group result, just over a third of the clinical children (n=14/40: 12 in age range of test and 2 outside age range) showed evidence of having oral motor difficulties on IM in particular, six of these being at the 1st percentile standard score 3). Of the fourteen children with oral motor difficulties, nine (CS5, LS5, TN5, AG6, CC6, HL6, TC6, TM6, SC7) also had significant difficulties with DDK accuracy.

8.4.2 DDK Consistency and Oral motor skills

Correlational analyses were carried out to examine the relationship between DDK consistency (binary) and raw scores for IM and SM for the clinical children (see table 8.7).

Table 8.7 Clinical children: Correlations (Spearman's rho) between DDK consistency (binary) and raw scores for Isolated Movements (IM) and Sequenced Movements (SM).

	Isolated movements (IM)	Sequenced movements (SM)
DDK Consistency (binary /24)	.184, p=0.268, ns.	0.87, p=0.604, ns.

Key: IM=Isolated movements; SM=Sequenced movements; ns=not significant.

There was no significant relationship between DDK consistency and raw scores on Oro-motor subtests of IM or SM. As reported under 8.4.1, just over a third of the children (n=14) showed evidence of having oral motor difficulties on IMs, including seven children (CS5, LS5, TN5, AG6, CC6, HL6, TC6) who had significant difficulties with DDK consistency as well as DDK accuracy.

8.4.2 DDK Rate and Oral motor skills

Correlational analyses were carried out to examine the relationship between DDK rate (mean rate in seconds per syllable) and raw scores for IM and SM for the clinical children (see table 8.8).

Table 8.8 Clinical children: Correlations (Spearman's rho) between DDK rate (in seconds per syllable) and raw scores for Isolated Movements (IM) and Sequenced Movements (SM).

	Isolated movements (IM)	Sequenced movements (SM)
DDK Rate (in seconds per syllable)	-.020, p=0.906, ns.	-.264, p=0.109, ns.

Key: IM=Isolated movements; SM=Sequenced movements; ns=not significant.

There was no significant relationship between DDK rate (in seconds per syllable) and raw scores on IM or SM Oro-motor subtests. However, of the fourteen children (see 8.4.1 and 8.4.2) who showed evidence of having oral motor difficulties on IMs, four (CS5, LS5, TN5 &TC6) had significant difficulties with DDK rate, in addition to DDK accuracy and consistency, and two (JC7 & SC7) had an isolated significant difficulty with DDK rate.

8.4.4 DDK task from the DEAP test

The DEAP test includes a DDK screen as part of the Oro-motor Assessment, which requires the child to repeat one DDK target, PAT-A-CAKE, either five times (children aged 3;0-4;11 years) or ten times (children aged 5;0-6;11 years). It is scored on three measures: (a) correct sound sequence, (b) intelligibility and (c) fluency, using a detailed scoring system of 0-3 points, which are added together to give a total score of N/9 points.

Since the current study involved a very detailed DDK assessment involving eight RW, NW and SS targets, the DEAP screening subtest was not administered to all the children. However, it was possible to take the 4 year old (n=10) children's data on five repetitions of PAT-A-CAKE and score it according to the DEAP instructions. In addition, a sample of thirteen of the children, aged 5 and 6 years, were asked to produce ten repetitions of PAT-A-CAKE and their responses were also scored according to the DEAP instructions (see appendix 8.9 for individual results).

The results from the 4 year olds (n=10), showed that only one child (AJ4) produced the correct sound sequence in all trials, and therefore scored 3 points on this measure. The remaining nine children produced an incorrect sound sequence in all trials and therefore scored 0 point on this measure. However, all the children scored at maximum (3 points) on the intelligibility measure (clear pronunciation, meaning it can be deciphered by the listener, in all the trials) and all except one child (SB4) scored at maximum on the fluency measure (fluent pronunciation, responses with no pauses or hesitations, in all the trials). When the 4 year old children's results were compared to the DEAP age norms, they all scored within the normal range, since a raw score of 6/9, is a standard score of 10, 50th percentile, for children aged 4;0-4;5 years and a standard score of 8, 25th percentile, for children aged 4;6-4;11 years. Thus, although only one child produced the correct sound sequence of /p-t-k/ on PAT-A-CAKE, all ten children scored within the normal range on the DDK screen.

Similar results were found for the sample of 5 and 6 year olds (aged 5;0-6;3) who produced 10 repetitions of PAT-A-CAKE. Like the 4 year old children, most were unable to maintain the correct sound sequence in all the trials, but all scored well on the fluency and intelligibility measures and therefore they scored a minimum of 6 points, which gives a standard score of 8, 25th percentile. In comparison, the detailed scoring system of this study identified thirty-three children (82.5%), including nineteen of the twenty-three children who carried out the DEAP DDK task, as having a significant difficulty (in comparison to age-matched typically-developing children) with one or more measures of DDK (accuracy, consistency, rate). Of these thirty-three children, twenty-nine showed a significant difficulty with DDK accuracy (equivalent to 'correct sound sequence' on the DEAP), either in isolation or in combination with significant difficulties on DDK consistency and/or DDK rate.

On the DEAP, the DDK scores for (a) correct sound sequence, (b) intelligibility, (c) fluency are combined together, but for the children in the current study, this resulted in their difficulties with accuracy being masked by their better scores on intelligibility and fluency. By separating the scores into three different components (accuracy, consistency, rate), as in the current study, the children's individual strengths and weaknesses with a DDK task are more transparent.

8.5 Accuracy of Single Consonant Sound production

The clinical children were asked to imitate twenty-four single consonant sounds after an adult spoken model. As described in Chapter Three, 3.7.4, a binary scoring system was used (1 point for a correct production and 0 point for an incorrect production) and consonant scores for individual children were calculated in comparison to the range of consonant sounds expected for a given age group, based on Appendix A of the DEAP manual and the DEAP Summary score sheet (Dodd et al., 2002). Since the number of consonants expected at a given age varied, scores were converted to percentage scores. Appendix 8.4 lists the percentage scores obtained by the individual children and table 8.9 presents the descriptive statistics for the clinical children as a group.

Table 8.9 Clinical children (n=40): percentage of single consonant sounds correct (in comparison to age norms from the DEAP (Dodd et al., 2002).

	Single sounds % Consonants correct
Mean	84.80
Standard Deviation	11.39
Median	83.50
Minimum	57.00
Maximum	100.00

Key: s.d. =standard deviation.

There was considerable individual variation, with a minimum score of 57% and a maximum of 100% (Median: 83.50%). Examination of the children's individual scores showed that ten (25%) children scored under 80% correct (LR4, SB4, TB4, CS5, JC5, KW5. OP5, SH5, TC6 & TM6) and four (10%) children scored under 70% correct (DC4, PG4, IT5 & AG6). Therefore, just over a third of the clinical children scored less than 80% correct on a single consonant sound imitation task, in comparison to age norms from the DEAP (Dodd et al., 2002).

8.5.1 DDK Accuracy and Accuracy of Single Consonant Sounds

Correlational analyses were carried out to examine the relationship between DDK accuracy (mean PCC) and percentage scores correct for single consonant sounds. A significant positive relationship was found (.474, p<0.01, moderate strength) - see figure 8.3.

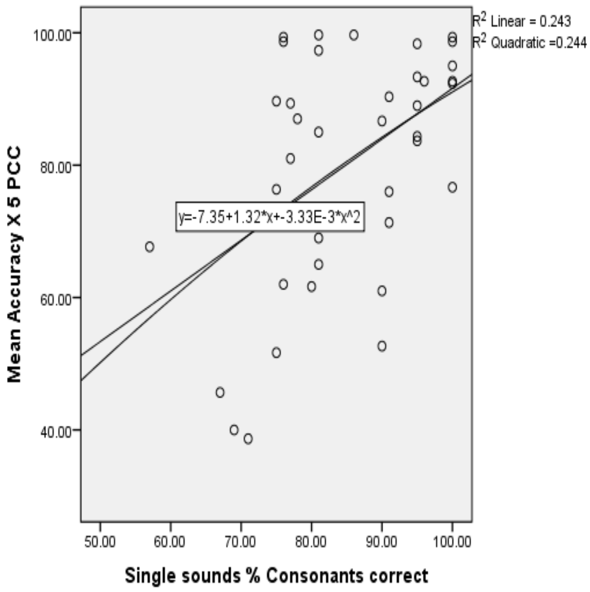


Figure 8.3 Relationship between DDK accuracy (mean PCC) and percentage of single consonant sounds correct.

Further correlational analyses were run to investigate the relationship between DDK accuracy (PCC) in each of the stimulus conditions (RWs, NWs and SSs) and percentage single consonant sounds correct (see table 8.10). Significant positive correlations were found in all conditions.

Table 8.10 Correlations (Spearman's rho) between DDK accuracy (PCC) by condition (RW, NW, SS) and accuracy of single consonants.

	Correlation coefficient	p value	Strength of relationship
Accuracy X 5 RW PCC	.458	p<0.01	Moderate
Accuracy X 5 NW PCC	.404	p<0.01	Moderate
Accuracy X 5 SS PCC	.471	p<0.01	Moderate

Key: Accuracy X 5=accuracy of five repetitions; RW=real word, NW=non-word, SS=syllable sequences, PCC=percentage consonants correct.

The results suggest that as a group, the clinical children's ability to articulate individual consonants in isolation is related to their ability to maintain accuracy on five repetitions of DDK targets, whether those targets are RWs, NWs, SSs or combined mean scores. Just over one third (n=14) of the clinical children scored below 80% single consonants correct and all but two (JC5 & SH5) of these children had significant difficulties with DDK accuracy. For each individual child, the single consonants not produced correctly (but which are expected for age) are listed in Appendix 8.4. Only six children (JJ4, DG5, EN5, PBS5, TN5, JC7) scored all single consonants correct as expected for their age group). The remaining thirty-four children (87.5%) produced between one and nine consonants incorrectly on the single consonant sound imitation task. Within this group of thirty-four children, five children (14.7%) produced one or more plosive sounds incorrectly; fourteen children (41.1%) produced the nasal sound /ŋ / incorrectly, eight children (23.5%) produced an approximant sound incorrectly; twenty-six children (76.4%) produced one or more fricative sounds incorrectly and twenty-four children (70.6%) produced one or more affricate sounds incorrectly.

Within the whole clinical group (n=40), seven children (17.5%) produced incorrectly one or more single consonants included in the DDK targets (see table 8.11) and all these children had significant difficulties with DDK accuracy. However, twenty-two children (55%), who had significant difficulty with DDK accuracy, produced all the consonants included in the DDK targets correctly suggesting that the ability to articulate the sounds in isolation cannot account for all difficulties on DDK tasks. Rapid repetition of targets as in DDK tasks taxes a child's speech production system far more than a when imitating single consonant sounds.

Table 8.11 Individual clinical children: incorrect production of single consonants included in DDK targets.

Child's ID.	Incorrect single consonants, occurring in DDK targets	Examples of RW, NW & SS targets affected
DC4	/g/, /l/	digger ; telephone
PG4	/k/, /g/, /l/	[ˈkəˈdəˈgə]; [ˈləˈtəˈbə]
IT5	/b/, /d/, /g/	[ˈlʌtɪbæks] ; cardigan
JB5	/l/	letterbox
KK5	/l/	[ˈtəˈləˈfə]
RH5	/d/	[ˈdægɪ]
HL6	/g/	[ˈdəˈgə]

Key: Child's ID=Child's identification code; RW=real word, NW=non-word, SS syllable sequences.

8.5.2 DDK Consistency and Accuracy of Single Consonant Sounds

Correlational analyses were carried out to examine the relationship between DDK consistency (binary) and percentage scores correct for single consonant sounds for the clinical children. No significant relationship (.014, p=0.934, ns) was found. Nevertheless, seven (LR4, SB4, TB4, CS5, KW5, OP5 & AG6) of the fourteen clinical children who scored below 80% single consonants correct had significant difficulties with DDK consistency, as well as DDK accuracy.

8.5.3 DDK Rate and Accuracy of Single Consonant Sounds

Correlational analyses were carried out to examine the relationship between DDK rate (mean, in seconds per syllable) and percentage scores correct for single consonant sounds for the clinical children. No significant relationship (.042, p=0.799, ns) was found. However, four of the fourteen children who scored below 80% single consonants correct, had significant difficulties with DDK rate, as well as DDK accuracy (TC6) or had significant difficulties with DDK rate, in addition to DDK accuracy and DDK consistency (SB4, CS5, KW5).

8.6 Accuracy of Single Word Naming

The clinical children were assessed on the Phonology Assessment of the *Diagnostic Evaluation of Articulation and Phonology* (Dodd et al., 2002), which comprises 50 pictures to be named (see Chapter Three, 3.5.7 for further detail). Their accuracy of single word naming was scored by percentage consonants correct (PCC). A full list of the children's PCC raw scores, standard scores and percentiles are listed in Appendix 8.5 and descriptive statistics of raw and standard scores are presented in table 8.12.

Table 8.12 Clinical children (n=40): Raw and standard scores on the single word naming test (DEAP Phonology Assessment, Dodd et al., 2002).

	Naming(PCC) raw score	Naming (PCC) std score
Mean	63.05	3.42
s.d.	18.32	1.08
Median	67.00	3.00
Minimum	25.00	3.00
Maximum	94.00	7.00

Key: s.d. =standard deviation;

Two children (JC7 and SC7) were outside the age range of the DEAP and therefore standard scores (and percentiles) could not be produced for these children. For the 38 children in the DEAP age range, the results showed considerable individual variation. However, only two of these (5.3%) scored within the normal range (standard score: 7-13) and thirty-two (84.2%) had a standard score of 3, the first percentile. The raw scores of the two children outside the age range of the DEAP, were also equivalent to a standard score of 3, first percentile, when compared to the oldest age range on the test (6.11 years). Thus, thirty-four (thirty-two within the DEAP test age range and two outside the DEAP test age range) of the forty children (85%) scored very poorly on this single word naming task.

8.6.1 Phonological Error Patterns on the Single Word Naming Task

A full list of the numbers and types of phonological error patterns (phonological simplification processes) made by the individual clinical children are listed in Appendix 8.5.

It was recognised that some error patterns were particularly likely to affect the accuracy of consonants included in the DDK targets. These were fronting, backing, voicing, stopping (if it affected /f/) and gliding (if it affected /l/). Therefore, for each child, a count was made of the occurrence of these specific error patterns (EPs) and these are listed in Appendix 8.6. Consideration was given to whether any of these errors could be resulting from articulatory difficulties by comparing the children’s performance on the single consonant sound imitation task to their performance on the single word naming task. In some cases, articulatory difficulties fully accounted for the child’s error pattern e.g. PG4 who is fronting but cannot articulate either /k/ or /g/ and JB5 who is gliding on /l/, but cannot articulate /l/ in isolation. In other cases, articulatory difficulties could only partially account for the child's error pattern e.g. DC4, RH5 and HL6 who are backing but who can articulate /k/ in isolation but not /g/. Error patterns which could entirely be accounted for by articulatory difficulties were excluded from the analysis below but those which could only partially be accounted for by articulatory difficulties were included.

The results showed that within the clinical group (n=40) 12 children (30 %) had one phonological EPs, which could affect the accuracy of the consonants in the DDK targets; 8 children (20%) had two EPs, and 1 child (2.5%) had three EPs, and none of these could be fully accounted for by articulatory difficulties. The most common EPs made by the children were fronting and gliding (affecting /l/), and less common EPs were backing, stopping (affecting /f/) and voicing.

8.6.2 DDK Accuracy and Accuracy of Single Word Naming

Correlational analyses were carried out to examine the relationship between DDK accuracy (mean PCC) and PCC scores on single word naming. Strong positive relationships were found between the two variables in each stimulus condition (RWs cc: .820, p<0.01; NWs cc: 753, p<0.01; SSs cc: .751, p<0.01) and on overall mean accuracy (cc:.793, p<0.01). Figure 8.5 shows the relationship between the DDK Accuracy (mean PCC) and single word naming (PCC).

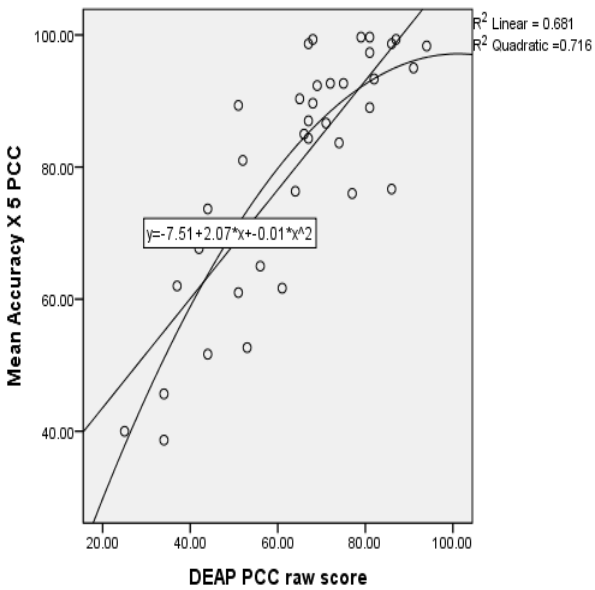


Figure 8.5 Relationship between DDK Accuracy (mean PCC) and single word naming (PCC).

The strong positive correlations found between the children's PCC scores on both of these tasks indicates a close relationship between the children's ability to maintain accuracy when repeating a DDK target, regardless of stimulus type, and their ability to name single words accurately.

Thirty-six of the thirty-eight children (94.7%) in the DEAP age range scored below the normal range and just over three-quarters (28/36) of these children had a significant difficulty with DDK accuracy. Of these twenty-eight children, twenty (71%) presented with one or more EPs (which had the potential to affect consonants included in the DDK targets) on picture naming and which could not be fully accounted for by articulatory difficulties. These error patterns are described as *phonological* by the authors of the DEAP, and therefore it might be expected they would affect RW targets more than NW or SS targets. However, the results in chapter four showed that as a group, the clinical children scored similarly for DDK accuracy in each condition (RWs, NWs, SSs), rather than showing a clearly differentiated profile. It seems plausible that *phonological* error patterns may occur across NW as well as RW conditions because the nonsense DDK targets in this study are legal English non-words and similar to the RW targets in terms of stress patterning as well as syllable structure, and therefore the children treated the NW targets in a similar way to RW. However this does not fully explain their performance on SS, which are not possible English words in terms of their stress pattern. An alternative psycholinguistic viewpoint is that it is not relevant to try and explain differences in performance on RW and nonsense targets on the basis of *phonological* error patterns, since such patterns are not entities; rather they are simply descriptions of errors that children make on speech output tasks, which originate at different processing levels, such as motor programming, motor execution, phonological representations, in individual children (see Stackhouse and Wells (1997) for further discussion).

8.6.3 DDK Consistency and Accuracy of Single Word Naming

Correlational analyses were carried out to examine the relationship between DDK consistency (binary) and PCC scores on single word naming. The results revealed a moderate positive relationship (cc: .33, $p<0.05$) between the two variables. Thirty-six of the thirty-eight children (94.7%) who were in the DEAP age range scored below the normal range on the single word naming task and 20/36 of these children had a significant difficulty with DDK consistency, in addition to DDK accuracy. Of these children, fifteen (75%) made one or more phonological error patterns on the naming task, which could not be fully accounted for by articulatory difficulties, but had the potential to affect the consonants included in the DDK targets.

8.6.4 DDK Rate and Accuracy of Single Word Naming

Correlational analyses were carried out to examine the relationship between DDK rate (mean in seconds per syllable) and PCC scores on single word naming. No significant relationship (cc: -.085, p=0.607) was found. Nevertheless, two (5.3%) of the thirty-six children in the age range of the DEAP who scored below the normal range, had an isolated significant difficulty with DDK rate and fifteen (41.67%) had a significant difficulty with DDK rate, either in addition to DDK accuracy or in addition to DDK accuracy and DDK consistency. Thirteen of these seventeen children (76.5%) who had a significant difficulty with DDK rate, had one or more phonological error patterns on the single word naming task, which could not be fully accounted for by articulatory difficulties, but had the potential to affect the consonants included in the DDK targets.

8.7 Consistency of Single Word Naming

A subset of the clinical children (n=16), namely those who were attending the specialist setting, were assessed on the Inconsistency Assessment from the DEAP (Dodd et al., 2002). The children named a set of twenty-five pictures in three separate trials within the same session. Each child's production of each target word was compared across the three trials: 1 point was allotted if there was any difference in their production across the three trials and 0 point if all three productions were the same, thus the higher the score the more inconsistent they were. The inconsistency score for each child was calculated using the following formula: the number of items which scored 1 /the number of items produced three times X 100 and recorded as a percentage score. Appendix 8.7 lists the children's individual inconsistency scores and group descriptive statistics are presented in table 8.13.

Table 8.13 Clinical children (n=16): DEAP inconsistency scores.

	DEAP Inconsistency scores
Mean	25.06
s.d.	15.79
Median	21.00
Minimum	8.00
Maximum	72.00

Key: s.d.=standard variation.

There was wide individual variation on the task, as shown by the minimum and maximum scores in table 8.13. However, the mean score was 25.06%, which is well below the 40% cut off point to be identified as being inconsistent. Whilst most children showed some variability when naming pictures three times, only two children (CS5 and KK5) reached the criteria to be considered inconsistent on the DEAP task.

8.7.1 DDK Accuracy and Consistency of Single Word Naming

Correlational analyses were carried out to examine the relationship between the children's DDK accuracy (PCC) and their Consistency of single word naming (percentage score). No significant relationship was found (cc: -.461, p=0.062) for the clinical children as a group (n=16). Nevertheless, all sixteen children showed some inconsistency on the single word naming task and thirteen of these sixteen (76.5%) had a significant difficulty with DDK accuracy either in isolation (n=1) or in conjunction with DDK consistency (n=4, including KK5 who scored above the 40% inconsistency cut off), or in conjunction with DDK rate (n=2), or in conjunction with DDK consistency & rate (n=5, including CS5 who scored above the 40% inconsistency cut off).

8.7.2 DDK Consistency and Consistency of Single Word Naming

Correlational analyses were carried out to examine the relationship between the children's DDK consistency and their single word consistency; note that these two sets of scores move in opposite directions: the higher the score on DDK consistency (/24), the more consistent the child is whereas the higher the score on the DEAP Inconsistency Assessment, the more inconsistent the child is. Therefore, a negative correlation would show a positive relationship. The results revealed a strong negative correlation between the children's DDK consistency and their single word consistency scores (cc: -.731, p<0.01) – see figure 8.6.

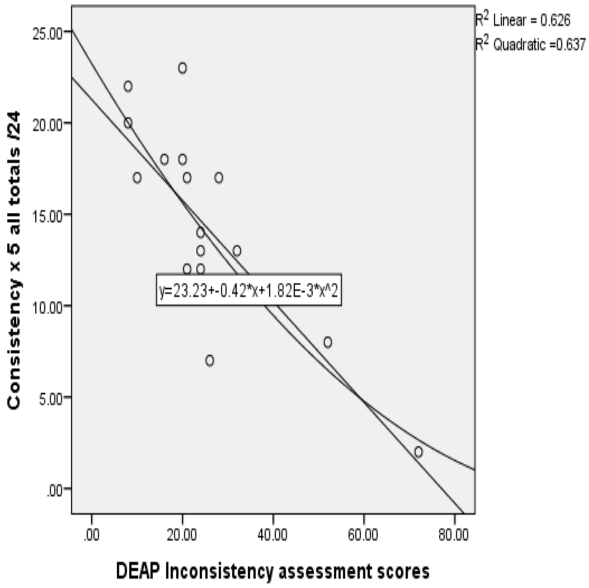


Figure 8.6 Clinical children (n=16): relationship between DDK consistency and consistency of single word naming.

Of the sixteen children who carried out the DEAP Inconsistency Assessment, seven had no significant difficulties with DDK consistency and nine had significant difficulties. Four of these nine children had a difficulty with DDK consistency and DDK accuracy (including KK5 who scored above the 40% inconsistency cut off), and five of the nine children had a difficulty with DDK consistency, DDK accuracy and DDK rate (including CS5 who scored above the 40% inconsistency cut off). Thus, over half the children who scored above 0% inconsistent on the single word naming task also had significant difficulties with DDK consistency, either in conjunction with DDK accuracy or in conjunction with DDK accuracy & DDK rate.

8.7.3 DDK Rate and Consistency of Single Word Naming

Correlational analyses were carried out to examine the relationship between the children's DDK rate and their single word consistency. No significant relationship was found (cc: .376, p=0.137). Of the sixteen children who carried out the DEAP Inconsistency assessment, seven had no significant difficulties with DDK rate and nine had significant difficulties. Two of the nine children had an isolated difficulty with DDK rate, two had a difficulty with DDK rate and DDK accuracy, and five had a difficulty with DDK rate, DDK accuracy and DDK consistency (including CS5 who scored above the 40% inconsistency cut off).

8.8 Connected Speech Rate

The children were asked to describe the three 'funny' pictures at the end of the DEAP Phonology Assessment and to describe five 'What's wrong?' cards, in order to collect elicited connected speech. Six utterances, usually three from each task, of varying length (but all longer than 3 words and involving a minimum of 3 syllables) were selected and timed using Praat (Boersma & Weenink, 2001). Short pauses and silences were included to mirror the method of recording for DDK rate, however any pauses longer than 0.25 seconds were excluded – see Chapter Three, 3.7.8 for further details. A mean connected speech rate in seconds per syllable was calculated, based on the six utterances sampled. A full list of the children's mean connected speech rates are listed in Appendix 8.8 and descriptive statistics are presented in table 8.14.

Table 8.14 Clinical children (n=40): connected speech mean rates in seconds per syllable.

	Mean rate in secs per syll
Mean	.39
s.d.	.08
Median	.39
Minimum	.22
Maximum	.57

Key: secs=seconds; syll=syllable; s.d.=standard deviation.

There was individual variation within the clinical group, from a minimum of.22 seconds per syllable (or 4.55 syllables per second) to a maximum of .57 seconds per syllable (or 1.75 syllables per second), but the mean and median scored were .39 seconds per syllable or 2.56 syllables per second. Thirty children performed within +/- 1 s.d. of the group mean and five children performed +1.0 - 1.5 s.d. or more above the group mean (i.e. spoke faster in connected utterances than the mean rate). Only five children spoke at a significantly slower rate in connected utterances than the mean rate: TB4 (-1.5 s.d.), CS5 (-2.0-2.5 s.d.), RB5 (1.0-1.5 s.d.), HL6 (-1.5 s.d.) and JC7 (-1.5-2.0 s.d.).

No data was collected from the typical children, but the results for the clinical children can be broadly compared with published norms on speaking rate from other studies (see Table 8.15).

Table 8.15 Speaking rates (with pauses excluded) reported in the literature for typically-developing children aged 3-7 years.

3 years	4 years	5 years	6 years	7 years
3.03-3.46 syll/secs. Equivalent to: .33-.28 secs/syll. (Robb & Gillon, 2007)	3.75 syll/secs. Equivalent to: .27 secs/syll. (Walker & Archibald, 2006)	3.39 syll/secs. Equivalent to: .29 secs/syll. (Walker & Archibald, 2006)	3.76 syll/secs. Equivalent to: .27 secs/syll. (Walker & Archibald, 2006)	
		4.01 syll/secs. Equivalent to: .25 secs/syll. (Haselager et al. 1991)		4.51 syll/secs. Equivalent to: .25 secs/syll. (Haselager et al. 1991)

As a group, the clinical children in this study therefore produced slower connected speech rates than the youngest typically-developing children reported in the studies above. However, some individual children in the age groups 4, 5 and 6 years produced similar connected speech rates to those reported in these normative studies.

8.8.1 DDK Accuracy and Connected Speech Rate

Correlational analyses were carried out to examine the relationship between the children's DDK accuracy (binary) and their connected speech rate. No significant relationship was found (cc:=.039, p=0.812). Of the five individual children who spoke significantly slower than the group mean, three had difficulties with DDK accuracy: two had a difficulty with DDK accuracy and DDK consistency (TB4 and HL6) and one had a difficulty with DDK accuracy, DDK consistency and DDK rate (CS5).

8.8.2 DDK Consistency and Connected Speech Rate

Correlational analyses were carried out to examine the relationship between the children's DDK consistency (binary) and their connected speech rate. No significant relationship was found (cc:=.027, p=0.871). Of the five individual children who spoke significantly slower than the group mean, three had difficulties with DDK consistency: two had a difficulty with DDK consistency and DDK accuracy (TB4 and HL6) and one had a difficulty with DDK consistency, DDK accuracy, and DDK rate (CS5).

8.8.3 DDK Rate and Connected Speech Rate

Correlational analyses were carried out to examine the relationship between the children's DDK rate (mean in seconds per syllable) and their connected speech rate. No significant relationship was found (cc: .292, p=0.072). Of the five individual children who spoke significantly slower than the group mean, three had difficulties with DDK rate: two had a difficulty with DDK rate only (RB5 and JC7) and one had a difficulty with DDK rate, DDK accuracy and DDK consistency (CS5).

8.9 Summary of Main Group Findings

Table 8.16 provides a summary of the relationships between the DDK measures and the other speech measures for the children with speech difficulties.

Table 8.16 Summary of relationships between DDK Accuracy, DDK Consistency, DDK Rate and other measures.

	Accuracy of lexical representations	Oral motor skills	Accuracy of single consonant sounds	Accuracy of single word naming	Consistency of single word naming	Connected speech rate
DDK Accuracy	.574, p<0.01**	ns	.474, <0.01,**	.793, p<0.01**	ns	ns
DDK Consistency	.367, p<0.05*	ns	ns	.33, p<0.05*	-.731, p<0.01**	ns
DDK Rate	ns	ns	ns	ns	ns	ns

Key: ns=not significant; *=significant at p<0.05 level; **=highly significant at p<0.01 level.

The main findings were that:

1. DDK Accuracy: a strong relationship was found between DDK Accuracy and accuracy scores on other tasks: Accuracy of lexical representations, Accuracy of single consonant sounds and Accuracy of single word naming. The relationship between DDK Accuracy and consistency of single word naming was not significant but was approaching significance (-.461, p=0.062).
2. DDK Consistency: a strong relationship was found between DDK Consistency and Consistency on single word naming. A significant but weaker relationship was found between DDK Consistency and with Accuracy of single word naming and Accuracy of lexical representations, but the relationship between DDK Consistency and accuracy of single consonant sounds was not significant.
3. DDK Rate: No significant relationship was found between DDK rate and any other measure.
4. No relationship was found between any DDK measure (Accuracy, Consistency, Rate) and Oral motor skills.
5. No relationship was found between any DDK measure (Accuracy, Consistency, Rate) and Connected speech rate.

8.10 Conclusion of group findings

The results for the clinical children as a group suggest that for DDK accuracy and DDK consistency, but not for DDK rate, there is a relationship between DDK performance and other speech processing measures. In particular, DDK accuracy is strongly related to accuracy of single consonant imitation, single word naming and accuracy of lexical representations, and DDK consistency is strongly related to consistency of single word naming. No relationship was found between any DDK measure and oral motor skills or connected speech rate.

As individuals, the clinical children in this study had varying degrees of difficulty with the DDK measures (accuracy, consistency and rate) and furthermore varying patterns of performance on the speech processing variables. For each individual child, it is likely that a number of different factors are contributing to their difficulties with DDK tasks.

8.11 Individual findings

For the children with speech difficulties as individuals, their performance on the speech processing measures described in this chapter was combined with their DDK profile (see chapter seven) to see whether any unifying patterns of performance would emerge to support the identification of subgroups. This information is presented in table 8.17 below.

Table 8.17 Individual children's performance in each DDK profile on speech processing measures

	Accuracy of lexical representations	Oral motor skills	Accuracy of single consonant sounds	Accuracy of single word naming	Consistency of single word naming	Connected speech rate
DDK Profile1: Inaccuracy only						
DC4			X	X	NT	
PG4	X		X	X		
DG5	X			X	NT	
TM6		X	X	X	NT	
DDK Profile 2: DDK Inaccuracy and Inconsistency						
LR4	X		X	X	NT	
TB4			X	X	NT	X
JK5			X	X	NT	X
KK5			X	X	X	X
OP5			X	X		
RH5	X		X	X	NT	
AG6		X	X	X		X
CC6			X	X		X
HL6		X	X	X	NT	X
DDK Profile 3: DDK Slower rate only						
IF5			X	X	NT	X
RB5			X	X	NT	X
JC7		X		X		X
SC7		X	X	X		X

DDK Profile 4: DDK Inaccuracy and Slower rate						
MP4			X	X	NT	X
TH4			X	X	NT	X
IT5			X	X		
TC6		X	X	X		X
DDK Profile 5: DDK Inaccuracy, Inconsistency and Slower rate						
AJ4			X	X	NT	
EW4			X	X	NT	
JJ4					NT	
SB4			X	X	NT	X
CS5		X	X	X		X
EN5				X	NT	
JB5			X	X	NT	
KW5			X	X		
LS5		X	X	X		
OB5			X	X		
TN5		X		**X**	NT	
EC6		NT	**X**	**X**		X
DDK Profile 6: No significant DDK difficulties						
ChS5		X	**X**	**X**	NT	
JC5			X	X	NT	
PBS5		X		X	NT	X
RW5			X	X		
SH5			X	X		X
HM6		X	X		NT	
KH6		X	X	X	NT	

X=difficulty noted; NT=not tested.

No clear unifying patterns were identified in any of the DDK profiles. In a further effort to determine whether any clearly defined subgroups would emerge amongst the children with speech difficulties, it was decided to use a linguistic classification approach (Dodd, 1995; 2005) as well as to produce individual speech processing profiles using a psycholinguistic approach (Stackhouse and Wells, 1997). It was not possible to use the WHO ICF-CY medical approach as it is not fine-grained enough to examine the detailed information obtained on speech and DDK measures. However, relevant case history information and broad assessment details were recorded for each individual child included in the study (see Appendix 8.11).

8.11.1 Linguistic classification based on Dodd (1995; 2005)

Dodd et al. (2002) advise that the *Diagnostic Evaluation of Articulation and Phonology* is a diagnostic test battery and therefore, for clinical purposes, not all assessments should be administered. A SLP/SLT is advised to start with the Diagnostic screen, to determine if the child has a speech difficulty and then, based on the screen findings, select appropriate subtests to determine the nature of the child's speech difficulty. However, in this study, it was already known that the children had obvious speech difficulties (see inclusion criteria) so the DEAP subtests were used to provide information on different aspects of the children's speech output, as in other research studies (e.g. Dodd & McIntosh, 2008; McLeod et al., 2013).

Since the DEAP Inconsistency Assessment had only been administered to some of the children (n=16), this classification can only really be applied to this subset. For these children, an attempt was made to classify each child into the subgroups proposed by Dodd (1995; 2005): articulation disorder (AD), phonological delay (PD), consistent phonological disorder (CPD) and inconsistent phonological disorder (IPD) (see Chapter two: Literature review for further information). However, this was mainly unsuccessful as few children could be classified into these single subgroups. Therefore, a further attempt was made to examine whether classification might be possible by combining and/or modifying some of the subgroups. In particular, since many of the children had at least one or more consonant sounds they could not articulate, this involved combining *articulation difficulties* with the three phonological subgroups (PD, CPD and IPD). For this subset of the children, the following subgroups were identified: articulation difficulties only (A) (unable to produce one or more consonant or vowel sounds expected for age and no delayed or unusual phonological error patterns); phonological delay and articulation difficulties (PD + A); consistent phonological disorder and articulation difficulties (CPD+A); inconsistent phonological disorder and articulation difficulties (IPD+A);

unclassified –resolving speech difficulties (did not meet criteria for any of the other subgroups). In addition, one child met Dodd's criteria to be investigated for developmental verbal dyspraxia (DVD), since he demonstrated difficulties on the Oro-motor assessment, the articulation task and the Inconsistency Assessment.

Full details of the children's profiles of difficulties on the DEAP assessments are listed in Appendix 8.9. This information is summarised and combined with the children's subgroup classification under each DDK profile in the tables below:

Table 8.18 DDK Profile 1: DDK Inaccuracy only

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
PG4		X	X	X	X		CPD + A

X=difficulty noted; CPD =Consistent phonological disorder; A=Articulation difficulties.

Table 8.19 DDK Profile 2: DDK Inaccuracy and Inconsistency

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
KK5		X	X	X		X	IPD + A
OP5		X	X	X	X		CPD + A
AG6	X	X	X	X	X		CPD + A
CC6		X	X	X			PD + A

X=difficulty noted; CPD =Consistent phonological disorder; IPD= Inconsistent phonological disorder; PD=phonological delay; A=Articulation difficulties.

Table 8.20 DDK Profile 3: DDK Slower rate only

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
JC7	X	X (vowels)	X	X	X		CPD + A
SC7	X	X	X	X			PD + A

X=difficulty noted; CPD =Consistent phonological disorder; A=Articulation difficulties; PD=phonological delay.

Table 8.21 DDK Profile 4: DDK Inaccuracy and DDK Slower rate

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
IT5		X	X	X	X		CPD + A
TC6	X	X	X	X	X		CPD + A

X=difficulty noted; CPD =Consistent phonological disorder; A=Articulation difficulties;

Table 8.22: DDK Profile 5: DDK Inaccuracy, Inconsistency and Slower rate

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
CS5	X	X	X	X	X	X	DVD
KW5		X	X		X		CPD + A
LS5	X	X	X	X			PD + A
OB5		X	X	X			PD + A
EC6	NT	X	X	X			PD + A

X=difficulty noted; CPD =Consistent phonological disorder; PD=phonological delay; A=Articulation difficulties; DVD=Developmental verbal dyspraxia.

Table 8.23 DDK Profile 6: No significant DDK difficulties

Child's ID	Oro -M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsistent	Subgroup
RW5		X	X				A
SH5		X	X	X			PD + A

X=difficulty noted; A=Articulation difficulties; PD=phonological delay.

Observations about possible subgroups are limited by the small number of children (n=16) who carried out the full assessment battery from the DEAP (Dodd et al., 2002). However, the children who did carry out this task were distributed across the six identified DDK profiles. All of the children had articulatory difficulties (affecting production of one or more consonant sound) and therefore there were children in DDK profiles which involved DDK Inaccuracy (i.e. profiles 1, 2, 4 and 5), as well as in profiles where there was no DDK Inaccuracy (i.e. profiles 3 and 6).

Nine children were in a profile which included a difficulty with DDK rate (profiles 3, 4 and 5). Children in these categories were classified variously as having: phonological delay and articulation difficulties (n=4), consistent phonological disorder and articulation difficulties (n=4) and DVD (n=1).

Nine children were in a profile which included a difficulty with DDK consistency (i.e. in profiles 2 and 5). Of these nine, only two children (KK5, CS5) scored above the 40% criterion on the single word naming task from the DEAP Inconsistency Assessment. KK5 was classified as having IPD and CS5 as having DVD. Despite this small number, it is noteworthy that consistency of single word naming, was found to correlate strongly with DDK consistency for the children as a group.

In summary, the numbers of children are small and therefore findings need to be treated with caution. However, when the children were subdivided by their DDK profile, it was not possible to identify clearly defined subgroups using the linguistic classification approach (Dodd, 1995; 2005).

8.11.2 Psycholinguistic speech processing profiles (Stackhouse & Wells, 1997)

This study did not sample a full range of levels across the speech processing framework (Stackhouse & Wells, 1997) and therefore it was only possible to produce psycholinguistic profiles based on the levels assessed in this study. However, unlike for the Linguistic approach it was possible to include all the children with speech difficulties (n=40) in this approach. A full list of psycholinguistic profiles is given in Appendix 10. In tables 8.24 -8.29, the children's psycholinguistic profiles are listed under the relevant DDK profiles.

Table 8.24 DDK Profile 1: DDK Inaccuracy only

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
DC4		X	X	X	XXX	XX
PG4	X	X	X	X	XXX	XX
DG5	X	X			X	
TM6		X	X	X	XXX	XXX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX =difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Table 8.25 DDK Profile 2: DDK Inaccuracy and Inconsistency

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
LR4	X	X	X	X	XX	X
TB4		X			XX	XX
JK5		X	X	X	XXX	XX
KK5		X	X	X	XXX	XX
OP5		X	X	X	XXX	XX
RH5	X	X	X	X	XXX	XX
AG6		X	X	X	XXX	XXX
CC6		X		X	XX	XX
HL6		X	X	X	XXX	XXX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX =difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Table 8.26 DDK Profile 3: DDK Slower rate only: Psycholinguistic approach

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
IF5		X			X	XX
RB5		X		X	XX	XX
JC7		X				XX
SC7		X			XX	XX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX =difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Table 8.27 DDK Profile 4: DDK Inaccuracy and DDK Slower rate

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
MP4		X	X	X	XX	XX
TH4		X	X	X	XXX	XX
IT5		X	X	X	XXX	XX
TC6		X	X		XX	XXX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX =difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Table 8.28: DDK Profile 5: DDK Inaccuracy, Inconsistency and Slower rate: Psycholinguistic approach

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
AJ4		X	X	X	XXX	XX
EW4		X	X	X	XX	X
JJ4				X	XXX	X
SB4		X	X	X	XXX	XX
CS5	X	X	X	X	XXX	XXX
EN5		X			X	
JB5		X	X	X	XXX	X
KW5		X	X	X	XXX	XX
LS5		X	X	X	XXX	XXX
OB5		X	X		XX	XX
TN5		X				XX
EC6		X	X	X	XXX	XX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX =difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Table 8.29 DDK Profile 6: No significant DDK difficulties

Child's ID.	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/sg. sounds/ SS rep x 1
ChS5		X				XX
JC5		X				X
PBS5		X				XX
RW5		X				X
SH5		X				X
HM6						XX
KH6		X				XX

X=difficulty noted on one task; XX=difficulty noted on two tasks; XXX=difficulty noted on three tasks; Reps=representations; RW=real word; NW=non-word; SS=syllable sequences; x1=single repetition; x5=five repetitions; Oro=oral motor; sg. sounds=imitation of single sounds.

Some unifying patterns by psycholinguistic profile were found across the DDK profiles and these are summarised below:

Children in DDK profiles 3 and 6 have no evidence of DDK Inaccuracy, but all the children in these DDK profiles have evidence of motor execution difficulties and no difficulties with motor programs for real word repetition (on the DDK tasks). The main distinguishing characteristic between the children in DDK Profile 3 and 6, is that the children in profile 3 have evidence of motor planning difficulties, whereas the children in DDK profile 6 do not. Therefore, children in:

- DDK profile 6 (no DDK difficulties) have a psycholinguistic profile of problems with motor execution (for single consonant sound production and/or oral skills).
- DDK profile 3 (slower rate only) have a psycholinguistic profile of problems with motor planning and motor execution.

Children in DDK profiles 1, 2, 4 and 5 all have a difficulty with DDK Inaccuracy. Of these children:

- 22/29 have psycholinguistic profiles of problems at all output levels (motor programs, motor programming, motor planning and motor execution).
- 7/29, who are spread across these four DDK profiles, have less severe output deficits (affecting fewer levels).
- 5/29 also have input deficits (4 of these children had evidence of severe output deficits and one had less severe output deficits).

Therefore, there was more evidence of unifying characteristics across the DDK profiles when psycholinguistic profiles were considered. Nevertheless, there were still some "mixed" patterns of performance in each DDK profile, and it was difficult to detect unifying characteristics for individual DDK profiles.

8.12 Summary of individual findings

In chapter seven, six distinct DDK profiles were identified based on the performance of the individual children with speech difficulties on DDK measures of accuracy, consistency and rate. In this chapter, psycholinguistic profiles were identified (based on the tasks assessed in this study) for all the individual children with speech difficulties and a subset of these children (n=16) were also classified using a modified linguistic approach. The DDK profiles and speech processing profiles/classifications were then combined, with the aim of identifying any unifying characteristics, which might underpin potential subgroups. Some shared patterns of performance were identified across the DDK profiles using the psycholinguistic approach, when the profiles were divided into those which included DDK Inaccuracy and those which did not. However, it was not possible to find clearly-defined shared patterns in each DDK profile. This was also the case when the linguistic approach was used, since those children who were assessed on the full test battery, appeared to have mixed profiles of presenting difficulties in each DDK profile. However, it might have been easier to detect unifying patterns in the linguistic approach if the full set of children had been assessed on all the tasks.

Chapter Nine

Discussion

9.1 Introduction

The first aim of this study was to carry out a comprehensive investigation of the DDK skills of a group of children with speech difficulties in comparison to that of a group of typically-developing children. To do this, a range of different types and lengths of stimuli was used. The second aim was to investigate the relationship between the children's DDK performance and their performance on other speech processing measures. The final aim was to consider whether it was possible to identify distinct DDK profiles in the group of children with speech difficulties and if so, whether these profiles map onto subgroups of speech difficulties proposed in the literature.

Forty children with primary speech difficulties in the age range of 4;0 -7;11 were recruited. They had already been assessed and identified by a speech and language therapist as having speech difficulties and were receiving intervention to help them overcome those difficulties. All the children had normal hearing, typical or mildly delayed cognitive development and receptive language, expressive language developed to at least a 3-4 word level, and English as the primary language spoken at home. The recruited children with speech difficulties were assessed on a battery of tasks, including standardised tests and tasks specifically designed for this study. Forty age-matched typically-developing children were also recruited to compare performances on the non-standardised tasks.

The specific research questions set at the end of Chapter 2 will now be discussed with reference to the literature review and in the light of the results reported in Chapters 4-8.

9.2 DDK Performance on Measures of Accuracy, Consistency and Rate

Research questions

1. How do a group of children with speech difficulties (aged 4-7 years) perform on DDK tasks measured by (a) Accuracy, (b) Consistency and (c) Rate?

2. How does the performance of a group of children with speech difficulties on DDK tasks compare to a group of age-matched typically-developing children?

9.2.1 DDK Accuracy: Single repetitions

For syllable length, the clinical children performed as expected from studies of children with speech difficulties of varying types reported in the literature; that is they were more inaccurate when repeating longer spoken targets. For example, Leitao et al. (1997) reported that 6 year old children with either isolated speech difficulties or with combined speech and language difficulties performed more poorly on a multisyllabic word repetition task than age-matched typically-developing children or children with isolated language difficulties. Similarly, Lewis et al. (2004) reported findings on multisyllabic word repetition from a longitudinal study of three groups of children with speech difficulties. At pre-school age (4-6 years), children with isolated speech difficulties outperformed children with a combined speech and language difficulty and children described as having childhood apraxia of speech (CAS). By school age (8-10 years), the children with CAS still had significant persisting speech difficulties and continued to score more poorly than the other two groups on multisyllabic word repetition.

In comparison to the clinical children, the typical children in the current study repeated single DDK targets equally well (at or near ceiling) regardless of their syllable length. This finding is different from others reported in the literature for children in the age range 2;0-7;11 who have been found to repeat shorter targets (words and non-words) more accurately than longer targets (Roy & Chiat 2004; Chiat & Roy, 2007; Vance et al., 2005; Stackhouse et al., 2007). The result also differs from the findings reported by Williams and Stackhouse (2000) from their cross-sectional normative DDK study closely resembling the current study, where on single repetition, the children (n=30) demonstrated a significant main effect of age (3, 4, 5 years) and of stimulus length (2 vs. 3 syllables).

The likely explanation for the difference in the typical findings, lies with the small number of target items and the relative simplicity of the stimuli included in the current study. The typically-developing children aged 4-7 years performed at or near ceiling on single repetition indicating that the targets were not challenging enough. In comparison, studies by Vance et al. (2005), Roy and Chiat (2004); Chiat and Roy (2007) included more items and a greater range of syllable lengths (one to four syllables) and complexity (e.g. clusters were included). In the case of the Williams and Stackhouse (2000) study, although only 2 and 3 syllable targets were included, there were more items than in the current study (16 vs. 8), and they sampled a greater range of consonant sounds. Furthermore, the upper age range of the children was 5.11 years in comparison to 7.11 years in the current study, and this may also account for the differing results.

For stimulus type, neither the clinical nor typical children in the current study performed as expected given the reports in the literature. They did not show better accuracy on real word repetition in comparison to non-word repetition as previously found in studies of children in the age group 2-7 years (Roy & Chiat, 2004; Chiat & Roy, 2007; Vance et al., 2005; Stackhouse et al., 2007). Both the clinical and typical children performed similarly across the stimulus conditions (RW, NW, SS) which replicates the finding reported by Williams and Stackhouse (2000) in their cross-sectional normative DDK study.

The discrepant findings with other studies which have investigated repetition skills may again be explained by the targets selected for this study. Studies have shown that children find it easier to produce NWs which most closely resemble RWs (Dollaghan et al., 1995; Munson et al. 2005; Gathercole, 2006; Chiat & Roy, 2007). In the current study, the NW targets closely resembled the RWs in terms of consonant sequence, stress patterning and syllable structure, with the only difference being in the constituent vowels. This close similarity between NW and RW targets may explain why the children scored similarly on both these stimulus types. It appears they treated both RWs and NWs the same. However, this explanation cannot fully account for why the children also scored similarly on SS targets, where there is a difference in vowels and also in stress patterning. The SS targets were presented with no more stress on one syllable than the others and therefore they constitute illegal non-words in spoken English, as all words of more than one syllable have to have at least one perceptibly stressed syllable. Since the SS targets were presented in the same assessment session in which other repetition targets (RWs and NWs) were also presented, it seems probable that the children assumed they were being asked to repeat 'verbal' targets and therefore did as asked, without taking too much notice of specific issues such as legal or illegal stress patterning. A similar explanation was expressed by Shriberg et al. (2009) when discussing the design of *The Syllable Repetition Test* (SRT). Like the SS targets in the current study, each syllable of the SRT targets (eight bi-syllabic, six tri-syllabic and four quadruple syllable targets) is presented with no more stress on one syllable than the others. Shriberg et al. (2009) hypothesised that children would perceive these syllable strings as potential words, even without the presence of stress cues.

9.2.2 DDK Accuracy: Five repetitions

The present study is unusual in that it included measures of both single and five repetition accuracy on different stimuli types and length. As a result there is limited evidence available to make direct comparisons between its findings and other published investigations of DDK accuracy in children with specific speech difficulties. Further, few studies have included both bi-syllabic and tri-syllabic targets and therefore a comparison between children's performance on 2 vs. 3 syllable targets has not been possible. However, some normative studies have included DDK targets of differing lengths, and have found that children are more accurate on 2 syllable compared to 3 syllable targets (Henry, 1990; Williams & Stackhouse, 2000).

One key finding of the current study is however consistent with other reported DDK findings for children with speech difficulties: it is challenging for them to maintain accuracy on repeated productions of a tri-syllabic target. Reports of consonant sequencing difficulties or of children being unable to produce the required consonant sequence at all are common (Yoss & Darley, 1974; Henry, 1990; Bradford & Dodd, 1996; Thoonen et al., 1996; 1999; Lewis et al. 2004; Preston & Edwards, 2009; Wren et al., 2012). This finding has been frequently reported despite methodological differences between studies in terms of the specific targets included (e.g. real words or nonsense), the number of repetitions required (e.g. between 5 and 12 repetitions), the method of collection (e.g. time-by-count or count-by-time), the scoring methods employed (e.g. whole target correct, number of consonants correct) and the methods of analysis (accuracy, consistency, rate). However, Dodd and McIntosh (2008) reported that only 3.9% of seventy-eight children aged 3;1-5.6 with speech difficulties performed below the normal range on the DDK task from the DEAP Oro-motor assessment (Dodd et al., 2002). This discrepant finding may be attributable in part to age differences in participants since older children were included in the above studies, with the exception of Henry (1990). However, there is also a difference in the severity and nature of the children's speech difficulties. Although all the children in the Dodd and McIntosh (2008) study had to perform more than 1 s.d. below the mean on the DEAP Phonology test, the authors excluded children with neurological or cognitive impairment, as well as any child with a high level of inconsistency. Thus, children with severe and complex speech difficulties did not take part in the study. In comparison, the other studies listed above included children described as having severe speech difficulties (Henry, 1990; Bradford & Dodd, 1996; Thoonen et al., 1996; 1999; Lewis et al., 2004) and/or persisting speech difficulties (Preston & Edwards, 2009; Wren et al, 2012). Furthermore, children in the Dodd and McIntosh (2008) study were recruited following referral by parents which may have led to children with less severe speech difficulties being recruited, whereas children in most of the other studies (with the exception of Wren et al., 2012) were recruited following referral by SLPs/SLTs.

As for stimulus length, few studies which have reported DDK findings for children with speech difficulties have investigated their performance on different types of stimuli. One exception is the study by Murray et al., (2015) who assessed children with CAS, aged 4-12 years, on the RW and SS tri-syllabic targets from the Oral and Speech Motor Protocol (Robbins & Klee, 1987). They reported that maintaining DDK accuracy on the tri-syllabic SS target was particularly challenging for the children, which is in keeping with the findings of the current study.

Findings from the current study for the typical children are supported by the few normative studies which have included DDK targets of differing lengths (e.g. Henry, 1990; Williams and Stackhouse, 2000) and different types of stimuli (Williams & Stackhouse, 2000), i.e. that typical children are more accurate on RW targets than other targets and on shorter than longer targets.

As in other DDK studies which have reported on accuracy and included children both with and without speech difficulties (e.g. Yoss & Darley, 1974; Henry, 1990; Bradford & Dodd, 1996; Thoonen et al., 1996; 1999; Preston & Edwards, 2009), age-matched typically-developing children in the current study outperformed the children with speech difficulties.

9.2.3 DDK Consistency

Few published studies of DDK in children with speech difficulties have included a measure of consistency and therefore, comparison of the current study results with previous studies is limited. However, Preston and Edwards (2009) reported that adolescents with persisting speech difficulties were significantly more variable in their DDK productions of a tri-syllable than normally-speaking peers. Although the current study included younger groups of clinical and typically-developing children, it still replicates the findings of Preston and Edwards (2009). The clinical group in both studies were less consistent than their typically-developing peers and they demonstrated a higher level of individual variation.

Similarly, as for DDK studies of children with speech difficulties, there are few published studies that have included a measure of consistency when investigating typically developing children and therefore there is little information available with which to compare the current findings from the typical group. However, Williams and Stackhouse (2000) did include a measure of consistency and reported that their 3-5 year old typically-developing participants were generally very consistent in their DDK productions. This was true even for the youngest age group of 3 year olds, despite them being quite inaccurate in their speech production (Williams & Stackhouse, 2000). Therefore, the current study results for typically-developing children, aged 4-7 years, are in keeping with those of Williams and Stackhouse (2000).

9.2.4 DDK Rate

As a group, the children with speech difficulties in the current study produced slower DDK rates than their typically-developing peers, which replicates the findings of previous studies (e.g. Yoss and Darley, 1974; McNutt, 1977; Crary and Anderson, 1990; Henry, 1990; Thoonen et al., 1996). However, this has not been a universal finding; for example, Preston and Edwards, (2009) found there was no difference in DDK rates produced by adolescents aged 10-14 years with residual speech difficulties and normally-speaking peers, whereas DDK accuracy and DDK consistency did differentiate between the groups. The findings for rate by Preston and Edwards (2009) differed from those of McNutt (1977) despite the participants in both studies being adolescents with residual speech difficulties. There was a slight difference in age of the participants in the two studies (12-15 years in the McNutt study vs. 10-14 years in the Preston & Edwards study) which may have accounted for these results. However, there were also other methodological differences between the two studies and one or more of these factors may have also influenced the results. For example, the target selected (bi-syllabic in the McNutt study vs. tri-syllabic in the Preston & Edwards study); the method of collection (count-by-time in the McNutt study vs. time-by-count in the Preston & Edwards study) and the method of recording (strip-recorder in the McNutt study vs. digital waveforms in the Preston & Edwards study). In addition, the differing results may be accounted for by the small numbers recruited and the likely heterogeneity of the participants whose speech difficulties had persisted into adolescence. Finally, the relatively weak reliability of DDK measurement in general (Gadesmann & Miller, 2008) may have contributed to the differing results.

The finding that children with speech difficulties, as a group, were faster on 2 syllable targets than on 3 syllable targets in the present study is in keeping with the findings reported by Henry (1990). However few other studies of children with speech difficulties which have reported on rate, have included both bi-syllabic and tri-syllabic targets and therefore the results from the current study cannot be compared further. Some studies have only included bi-syllabic targets (e.g. McNutt, 1977), or tri-syllable targets (e.g. Preston & Edwards, 2009), whilst others have included a combination of mono-syllabic and tri-syllabic targets (e.g. Yoss & Darley, 1974; Thoonen et al., 1996; 1999). Yaruss and Logan (2002), in a normative study, recommended that it was only necessary to include a tri-syllabic target since previous studies had indicated strong correlations between DDK rates based on tri-syllabic, bi-syllabic and mono-syllabic targets (Hale et al., 1992; Wolk et al., 1993). This recommendation is not supported by the findings from the clinical children in the current study.

As for stimulus length, the findings for stimulus type in the current study are difficult to compare as few published DDK studies of children with speech difficulties have included NW stimuli. Although there is a reasonably large body of work which has reported on single NW repetition by children with speech difficulties (e.g. Nathan et al., 2004; Munson et al., 2005; Shriberg et al., 2012), this is not matched by evidence for NW repetition in DDK tasks. The only study which can be directly compared to the current study is the normative DDK cross-sectional study of 3-5 year old children, reported by Williams and Stackhouse (2000), since it included NW targets in addition to RW and SS targets. The 3 year old children in that study produced similar rates on all target types, but the 5 year old children showed a more differentiated performance with the slowest rates being produced on NW targets. The results of the current study for both the typical and clinical children therefore replicate the Williams and Stackhouse (2000) findings for 5 year old children.

9.2. 5 Relationships between DDK Measures

Research questions

Is there a relationship between DDK accuracy and (a) DDK consistency and (b) DDK rate?

9.2.5.1 DDK Accuracy and DDK Consistency

The finding of a strong positive relationship between accuracy and consistency in both the clinical and typical groups in the current study was not a surprising result given that accuracy and consistency measures are not independent of one another i.e. to be accurate you have to be consistent. For example, Preston and Edwards (2009) described production variability as a feature of DDK accuracy, since variability arises from attempts at accuracy that fail, and Marquardt et al. (2004) reported that greater accuracy demonstrates less inconsistency.

Few studies of children with speech difficulties have specifically reported both DDK accuracy and DDK consistency, which limits direct comparisons with the current study findings. One exception is the study by Preston and Edwards (2009) which included a measure of production variability in addition to a measure of accuracy. They summed the number of different ways that the DDK tri-syllable /pʌtʌkʌ/ was produced in 40 productions (10 repetitions in four trials), and found that adolescents with residual speech sound errors were both more inaccurate and more variable than normally-speaking peers. The results from the current study therefore corroborate these findings as the children with speech difficulties (aged 4-7 years), as a group, were both less accurate and less consistent than the age-matched typically-developing children.

In their normative study of children aged 3 -5 years, Williams and Stackhouse (2000) measured accuracy and consistency in a similar way to the methods utilised in the current study. They found that under 4 years, the typical children were more consistent than accurate, but after this time, accuracy and consistency were generally in line with each other. Two-thirds of the typical children in the current study performed like the 4+ year old children in the Williams and Stackhouse (2000) study since they were both accurate and consistent. In comparison, two-thirds of the children with speech difficulties in the current study performed more like the 3 year olds, since they were more consistent than accurate.

9.2.5.2 DDK accuracy and DDK rate

The relationship between speed and accuracy on speech tasks has been debated in the literature for decades. Children with immature speech motor skills may slow their rate of production in an effort to maintain accuracy, resulting in an accuracy-speed trade off. However, few DDK studies have included both measures of accuracy and rate and therefore it has not been possible to establish this empirically. Williams and Stackhouse (2000) provided some informal evidence of an accuracy-speed trade off, however, no specific correlations were calculated to measure this relationship. They observed that individual typically-developing children aged 3-5 years approached DDK tasks in different ways. Some children were very careful in their repetitions and therefore tended to be more accurate but slower on DDK rate. Other children, tended to produce fast rates but at the expense of accuracy. In comparison, Preston and Edwards (2009) did measure this relationship and reported no evidence of an accuracy-speed trade off in their study of adolescents with residual speech difficulties and normally speaking peers. As a trend, the clinical group produced slower rates and were more inaccurate, whereas the typical group produced faster rates but not at the cost of accuracy. The results of the present study replicate the findings of Preston and Edwards (2009). The children with speech difficulties, aged 4-7 years, were both less accurate and slower on DDK tasks than age-matched typically-developing children. Therefore, there was no evidence of an accuracy-speed trade-off.

Speed of production is generally regarded as a measure of speech motor competence (Fletcher, 1992). However, DDK rate alone was not able to differentiate between the typical and clinical groups in the Preston and Edwards (2009) study of adolescents. Rate has also not been found to be a sensitive measure in cross-sectional and longitudinal normative studies of younger children. For example, Williams and Stackhouse (2000) reported no increase in DDK rate between the ages of 3 and 5 years. Similarly, Walker and Archibald (2006) found there was no increase in speaking-rate between the ages of 4 and 6 years. In contrast to the rate only measure, Preston and Edwards (2009) reported that it was a combination of speed and accuracy which best differentiated adolescents with and without speech difficulties, indicating that factors other than speed need to be considered when measuring speech motor skill. The finding of a combination of difficulties with speed and accuracy was also common in the current study for children aged 4-7 years with speech difficulties.

9.2.6 Summary of findings for DDK measures

As a group, the children with speech difficulties performed significantly differently to the typically-developing children on DDK tasks on all three measures of accuracy, consistency and rate. Therefore, the findings support the use of these three measures when assessing DDK skills of children with speech difficulties as well as those of typically-developing children. This also suggests that DDK performance should not be considered to be a single entity. Instead, children’s performance on DDK tasks should be investigated on independent measures of accuracy, consistency and rate, so that results across studies can be compared and contrasted more in the future.

9.3 DDK Correlates with Other Speech Processing Measures

Research question

Is there a relationship between DDK measures and other speech processing measures for the children with speech difficulties?

9.3.1 Accuracy of lexical representations

One important finding of the current study was that accuracy of lexical representations on a mispronunciation detection task (MDT) correlated positively with both DDK accuracy (strong correlation) and DDK consistency (weak correlation). This suggests that DDK may not be purely an output task; rather a child's ability to maintain accuracy on repeated productions may be influenced by top-down as well as bottom-up speech processing (Stackhouse & Wells, 1997). Alternatively, it may be that accuracy of lexical representations and DDK accuracy share a separate unidentified component which accounts for the relationship.

Of note, strong positive correlations between accuracy of lexical representations and DDK accuracy on NW and SS targets, was found as well as on RW targets. As discussed under single repetitions above, it seems likely that the children treated all DDK targets (whether RW, NW or SS) as linguistic targets, despite their legal or illegal status and whether or not they had a meaning. Furthermore, in the case of repeated production, the rhythmic nature of the task may have helped to consolidate the children's view that these were all spoken words. This may explain why there were such strong correlations between accuracy of lexical representations and DDK accuracy on NW and SS, as well as RW targets.

9.3.2 Oral motor skills

Another key finding of this study was that accuracy of oro-motor skills did not correlate with any DDK measure, which questions whether DDK should be identified as an oro-motor task. Although DDK tasks are usually considered measures of speech motor performance (McCauley & Strand, 2008; Preston &Edwards, 2009), they are included in oral motor assessment procedures e.g. Oral and Speech Motor Control Protocol (Robbins & Klee, 1987); Oral Speech Mechanism Screening Examination – 3rd edition (St. Louis and Ruscello, 2000); Oro-motor Assessment from the DEAP (Dodd et al., 2002). Furthermore papers routinely report DDK findings under the heading of "oral diadochokinesia" (e.g. Henry, 1990; Modolo et al., 2010; Icht and David, 2014). The assumption, therefore, is that speech motor skills and oral motor skills are linked. However, such a relationship has been challenged in the literature on early speech development (Steeve et al, 2008). Instead, speech and non-speech oral behaviours are reported to involve separate co-ordinated structures which develop in parallel but along divergent paths (Rvachew & Brosseau-Lapre, 2012). Moreover, the muscles involved in speech from five different subsystems are unique in the body and specialized for the precise co-ordination of complex movement sequences at a rapid rate (Kent, 2004). The findings from the current study support a dissociation view between oral motor and speech motor skills. Although they involve the same anatomical structures, the ability to make and co-ordinate oral motor movements for non-speech tasks, such as blowing and licking, appears to be independent of the ability to make and co-ordinate movements of the articulators to produce individual and/or sequences of speech sounds. Whilst it is possible that a different result would have been found if a more detailed oral motor assessment had been administered rather than an oral motor screen, the current results indicate that DDK is not an oral motor measure. Instead, DDK provides a measure of speech motor competence which can be compared and contrasted with results from other speech tasks, independent of oral motor results.

9.3.3 Accuracy of single consonant sounds and Accuracy of single word naming

Accuracy of single consonant sound imitation and accuracy of single word naming correlated positively and strongly with DDK accuracy. Single consonant sound imitation and DDK accuracy are both measures of articulatory skill and therefore a relationship between these two measures was expected and confirmed by the study results. Unlike in studies of older children with speech difficulties who were all able to articulate the segments involved in the DDK targets (e.g. Preston & Edwards, 2009; Wren et al., 2012), seven children in the current study were unable to articulate one or more segments included in the DDK targets and this clearly affected their ability to be accurate on the DDK tasks. However, scores for DDK accuracy were based on a mean score across eight items, involving 2 and 3 syllable targets and a range of different consonant sounds and therefore the impact of these children's individual articulation difficulties was not as significant as would have been the case if only one target was sampled. Furthermore, twenty-two of the remaining thirty-three children had no difficulties in articulating any of the target segments, but still scored poorly on DDK accuracy. Thus, a difficulty in articulating one or more segments in the DDK targets could not account for all the children's DDK accuracy difficulties.

Single word naming measures phonetic as well as phonological skill, and therefore a relationship between naming and DDK accuracy was predicted and confirmed by the study results. In addition, accuracy of single word naming also correlated positively with DDK consistency (moderate correlation). Given the close relationship between accuracy and consistency identified in this study, these results were not unexpected.

Studies of older children with persisting speech difficulties have provided some evidence that children with articulatory difficulties perform more poorly on DDK accuracy than children with phonological difficulties. For example, Wren et al. (2012) reported that eight year old children who misarticulated /s/ or /r/ and children with a combination of significant phonetic and phonological difficulties were more likely than children with specific residual phonological difficulties to score poorly on DDK accuracy. In the current study, articulatory difficulties were common amongst the 4-7 year old children with speech difficulties, although often combined with phonological difficulties (see discussion of individual children, chapter 8). These articulatory difficulties may explain why over 70% of the children scored differently to typically-developing children on DDK accuracy.

Articulatory difficulties may also explain why children with DVD/CAS have been reported to perform poorly on DDK accuracy. Within a complex profile of difficulties, children with DVD/CAS typically have restricted phonetic repertoires (ASHA 2007; RCSLT, 2011). It seems possible that DDK accuracy is tapping into this specific phonetic aspect of the children's speech difficulties.

9.3.4 Consistency of single word naming

There is limited research evidence available to compare the finding of this study of a strong, positive relationship between DDK consistency and consistency of single word naming. However, Preston and Koenig (2011), investigated phonetic variability in twenty older children (CA: 9.02 -15.05) with residual speech sound difficulties. The test battery included a DDK task (as in Preston & Edwards, 2009) in addition to a 64-item picture naming task and a six item multisyllabic rapid picture naming task. Preston and Koenig (2011) measured token-to-token variability on the three tasks, through acoustic and transcription-based measures. On the DDK task, a count was made of the number of versions produced in forty repetitions (4 trials of 10 repetitions) and the two picture naming tasks were scored on the Error Consistency Index (ECI) (Tyler & Lewis, 2005) and the Total Token Variability (TTV) (Marquardt et al., 2004). The results showed moderate correlations between the ECI and TTV transcription-based measures, but neither the ECI nor the TTV scores were strongly related to the DDK variability scores. Furthermore, the acoustic measures (e.g. voice onset time on DDK, word and DDK durations and vowel formant values) did not correlate well with each other or with the transcription-based measures. Preston and Koenig (2011) concluded that children who were highly variable on one task were not necessarily highly variable on other tasks and therefore they cautioned against attempting to sub-group older children on the basis of phonetic variability (inconsistency).

In contrast to Preston and Koenig's findings (2011), the current study found a strong negative correlation between DDK consistency (binary scoring) and lexical consistency on the DEAP Inconsistency Assessment (Dodd et al., 2002). The correlation is negative because the two sets of scores move in opposite directions, i.e. the higher the score (/24) on the binary DDK consistency measure, the more consistent the child is; whereas the higher the score (/25) on the DEAP Inconsistency assessment, the more inconsistent the child is. All sixteen children who were assessed on the DEAP Inconsistency Assessment showed both significant difficulties with DDK consistency as well as some inconsistency on the DEAP lexical task. However, only 2/16 (12.5%) reached the 40% criterion identified by Dodd et al. (2002) to be classified as inconsistent. However, it remains debatable whether the DEAP Inconsistency Assessment is the optimal method for measuring in consistency/inconsistency in a child's speech, and furthermore whether the 40% cut off criterion is valid (Waring and Knight, 2013). Nevertheless, the current study results give some support to there being a relationship between inconsistent performance on DDK and inconsistency on other tasks.

The current study is different to the Preston and Koenig (2011) study in a number of ways: (a) it involved younger children with speech difficulties (aged 4;1-7;11), (b) the DDK tasks involved a much wider repertoire of targets (24, including 12 tri-syllables), (c) fewer repetitions were required on the DDK tasks (five in one trial), (d) an additional, binary measure of DDK consistency was made in addition to the count of the number of versions produced in repeated productions, and (e) a different measure of lexical consistency was included in the test battery. One or more of these variables may account for the difference in findings in the current study.

9.3.5 Connected speech rate

The finding of a lack of a significant relationship between connected speech rates and any DDK measure for the children with speech difficulties is perhaps surprising as it is usually thought that a DDK task broadly resembles spontaneous speech production, but without the linguistic complications (Tiffany, 1980; Yaruss & Logan, 2002). In the current study, connected speech was elicited through picture descriptions, and speaking rate was calculated using Praat (Boersma & Weenink, 2001) with short pauses included to mirror the rate calculations on the DDK tasks. It is possible that a stronger significant relationship may have been identified if connected speech had been sampled through a different task, for example a story re-tell task or sentence repetition and/or if a spontaneous conversational speech sample had been collected. In particular, sentence repetition may perhaps be more related to DDK as the child's task is simply to repeat back a spoken connected speech model, rather than generating language themselves. It is recommended that this could be explored in future studies by comparing DDK rate and connected speech rate elicited on different tasks.

9.3.6 Summary of findings for DDK Correlates

This is the first DDK study of children with speech difficulties which has investigated directly the relationships between the children's DDK performance and their performance on other speech processing tasks. The findings indicate that difficulties with accuracy and consistency shown by the children on DDK tasks were related to their wider difficulties with accuracy and consistency on other speech tasks. For accuracy, this included a positive relationship with accuracy of lexical representations as well as accuracy on other output tasks, suggesting that DDK should not be considered to be a purely bottom-up task. This view is further supported by the lack of a positive relationship between Oral motor skills and any DDK measure.

In comparison to accuracy and consistency, DDK rate was not found to correlate significantly with any of the speech processing measures investigated, including connected speech rate. This finding suggests that accuracy and consistency are more sensitive measures of DDK performance in children with speech difficulties than rate, despite it being the measure reported most frequently in the literature.

9.4 DDK and the Nature of Speech Difficulties in Children

9.4.1 Heterogeneity of the clinical group of children with speech difficulties

Although the children with speech difficulties as a group performed significantly differently to the typically-developing children as a group on DDK accuracy, consistency and rate, not all of the individual clinical children performed differently to the typical group on the DDK measures. Thus, there was evidence of heterogeneity within the clinical group. This did not appear to be related to age since non-significant results were found across the age groups. However, in the case of DDK accuracy, it did appear to be related specifically to the children's presenting speech difficulties as the individual children who performed no differently to the controls had no difficulty either in articulating any of the consonant segments included in the DDK targets or in using those consonants in words. Instead their speech difficulties were with the production or use of vowel sounds or consonant sounds other than those included in the targets presented (e.g. with fricative sounds other than /f/, or with affricate sounds). In most cases, these children had less severe speech difficulties than other children in the clinical group, since they only had difficulties with a single or small number of speech sounds or had reached the stage where their speech difficulties were mainly only evident at a connected speech level. Thus, their difficulties were mainly at the Assembly Phase of the *Developmental Phase Model* (Stackhouse and Wells, 1997), rather than at the Whole Word Phase or the Systematic Simplification Phase.

Individual differences in DDK performance were illustrated by Williams and Stackhouse (1998) in three case studies of children with speech difficulties, aged 4-8 years. All three children scored lower on DDK accuracy compared to typically-developing children aged 3-5 years, but only one of the three children scored differently to the controls on DDK rate and two of the three scored differently on DDK consistency. Williams and Stackhouse (1998) hypothesised that for individual children with speech difficulties, it would be possible to identify their DDK profile in terms of their performance on accuracy, consistency and rate and in comparison to age-matched typically-developing children. This hypothesis was investigated further in the current study.

9.4.2 DDK Profiles of children with speech difficulties

Research question

Is it possible to identify individual DDK profiles of accuracy, consistency and rate in a group of children with speech difficulties, in comparison to age-matched typically-developing children?

The results from the current study support Williams and Stackhouse's (1998) hypothesis that it is possible to identify DDK profiles for individual children with speech difficulties. Six distinct profiles were identified which included the three reported by Williams and Stackhouse (1998), namely 1) children who have an isolated difficulty with DDK accuracy; 2) children who have difficulties with DDK accuracy and DDK consistency; 3) children who have difficulties with DDK accuracy, DDK consistency and DDK rate, plus three more: 4) children who have an isolated difficulty with DDK rate; 5) children who have a difficulty with DDK accuracy and a difficulty with DDK rate; 6) children who have no difficulty with DDK tasks i.e. they performed no differently to the age-matched controls on DDK accuracy, DDK consistency and DDK rate.

The identification of distinct DDK profiles is further evidence of the heterogeneity within the group of children with speech difficulties.

9.4.3 Subgroups of children with different DDK profiles

Research question

Can the children with shared DDK profiles be regarded as forming distinct subgroups within the group of children with speech difficulties?

Although it was possible to classify a subset of the individual children using a modified linguistic approach (Dodd 1995, 2005) and to identify psycholinguistic speech processing profiles (Stackhouse & Wells, 1997), few unifying characteristics could be identified which might underpin a subgroup in the DDK profiles. Therefore the current study findings do not support Williams and Stackhouse's (1998) proposal concerning the aetiology of differing DDK profiles and suggests this was a too simplistic view.

However, the psycholinguistic approach revealed some common ground across the DDK profiles. For example, when the DDK profiles were split into those involving DDK Inaccuracy and those not involving DDK Inaccuracy, some unifying characteristics emerged (see chapter 8, 8.11.2). The majority of the children who had accuracy difficulties on the DDK tasks had problems at all output levels (motor programs, motor programming, motor planning and motor execution) and a small number also had input difficulties. In comparison, the children who had no difficulties with DDK accuracy had difficulties at fewer processing levels. However, they all had some difficulties with motor execution (on single sound imitation and some also had difficulties with oral skills). Although these children had a history of having more severe speech difficulties in the past, examination of the individual children's current profiles revealed that their particular articulation difficulties did not affect the DDK target consonants directly and/or that their difficulty was mainly with vowels which were not scored. This may account for these children's better scores on accuracy than children with other DDK profiles.

Nevertheless, the absence of difficulties on DDK accuracy for this group of children appears to be a different finding to that reported by Wren et al. (2012), who found that 8 year old children with both mild and more severe articulation difficulties made accuracy errors on DDK tasks. The differing result might be explained by the number of repetitions the children were asked to make. In the current study, they were only required to produce five, whereas in the Wren et al (2012) study, they were required to repeat the syllable sequences rapidly over a period of at least 10 seconds. It is possible that the children in the current study in DDK profile 6 (no difficulties on DDK accuracy, consistency or rate) would have made more accuracy errors had they been asked to produce a greater number of repetitions i.e. if their speech production system was being more taxed.

It seems possible that the lack of any strong evidence of unifying characteristics in the remaining DDK profiles may be accounted for by the relatively small number of children included in the current study. Thus, in a larger cohort, unifying patterns may be more visible. Alternatively, it may be that other factors are involved which were not fully examined in the current study, for example the amount of speech and language therapy input the children had received and/or the children's performance on tasks not included in this study (e.g. real and non-word discrimination or phonological awareness tasks). It is also possible that the behaviour of a few younger children who were not fully engaged with some tasks may have affected the results, for example by producing a slower rate than their maximum performance on one or other DDK task.

The failure to identify subgroups within the group of children with speech difficulties replicates the findings of Preston and Koenig (2011) who were unsuccessful in sub-grouping a cohort of twenty adolescents with residual speech difficulties on the basis of phonetic variability from an oral DDK task and a rapid multisyllabic picture naming task.

9.4.4 Classification of children's speech difficulties

The above results concerning the heterogeneity of the children with speech difficulties has a relevance to the unresolved debate in speech pathology over the best way to classify children's speech difficulties. In particular, debate continues as to whether or not they can be subdivided and on what basis this distinction should be made. A number of proposals have been put forward from differing medical, linguistic and psycholinguistic theoretical perspectives. These include classification by aetiology; surface speech errors on assessment tasks; speech processing skills on a profile; the developmental phase of speech development which best describes speech performance at a particular time point.

Dodd (1995; 2005) is particularly known for her work on subgrouping children by their surface speech errors. She has proposed four subgroups: articulation disorder, phonological delay, consistent phonological disorder and inconsistent phonological disorder. In the present study, it was not possible to divide the subset of children (n=16) who completed the full battery of tasks from the DEAP (Dodd et al. 2002) into these four subgroups. In particular, a large number of children had articulatory difficulties, but these were not isolated to /s/ or /r/ as described by Dodd (1995; 2005) as an articulation disorder. However, articulatory difficulties, affecting other consonant sounds, are not recognised in Dodd's subgroups and therefore modified subgroups had to be created in this study by combining articulatory difficulties with the three subgroups involving phonological difficulties (phonological delay, consistent phonological disorder and inconsistent phonological disorder. When the children's DDK profiles were combined with their linguistic classification, no clear unifying characteristics could be found.

In contrast, psycholinguistic approaches, such as the approach devised by Stackhouse and Wells (1997), do not generally attempt to subdivide children with speech difficulties into distinct groups. Instead, they aim to describe the speech processing strengths and weaknesses of an individual child, regardless of any label they may have been given e.g. DVD/CAS. Furthermore, they consider a child's processing abilities at input and stored representational levels, in addition to an output level. In the current study, the Stackhouse and Wells (1997) approach was utilised and individual speech processing profiles were drawn up for each child based on their performance on the tasks sampled. Although it was not possible to identify exactly-matched shared psycholinguistic profiles by the children in each DDK profile, some unifying patterns of processing breakdown could be identified. When accuracy on DDK tasks was examined in particular, children who had difficulties with DDK accuracy showed a different pattern of processing breakdown to those who had no such difficulties: they tended to have difficulties at more processing levels than children who did not have a difficulty with DDK Accuracy. Further investigation of the children's input and representational skills may have revealed more distinct patterns of speech processing breakdown. This was not possible in the present study but is recommended for future studies.

A further advantage of the psycholinguistic approach was in explaining the processing demands which the different DDK tasks make on a child. For example, DDK tasks have been described as "motorically challenging" (Murray et al., 2015), but this description gives no explanation of what exactly that means. In comparison, the psycholinguistic approach provides an explanation of the processing routes involved in DDK tasks involving different stimuli (see Chapter Three, 3.5.1, 3.5.2, 3.5.3) and allows a comparison to be made with processing involved in other speech tasks e.g. single sound production vs. repeated production as in DDK tasks. In terms of output processing, a DDK task is more motorically challenging than a single sound imitation task since it involves motor planning skills to maintain production over the required number of repetitions, in addition to motor programming skills (particularly if it involves a non-word target) as well as motor execution skills. In comparison, a single sound imitation task only involves motor execution skills and thus makes less motor processing demands on the child. Furthermore, the current study results found strong correlations between accuracy of lexical representations and DDK accuracy on all stimuli, suggesting that children appear to draw on stored representations as well as lower level processing skills in

DDK tasks. Alternatively, it could be that some other component is involved which is related to both DDK accuracy and accuracy of lexical representations. For individual children who find DDK tasks difficult, there may be more than one underlying explanation to account for their difficulties.

9.4.5 DDK as a clinical marker of DVD

In the literature poor performance on DDK tasks (accuracy and /or rate) has been particularly associated with a particular subgroup of children, namely those with DVD/CAS. The speech difficulties of children with DVD/CAS have been described as motor planning and/or motor programming difficulties and DDK tasks have been thought to be an appropriate measure to identify these motor difficulties. Thus, historically, DDK has been proposed to be a clinical marker for DVD/CAS (Yoss and Darley, 1974; Aram & Glasson, 1979; Dewey et al. 1988; Crary and Anderson, 1990; Thoonen et al., 1996; 1999). Recently, Murray et al. (2015), have reiterated that DDK accuracy in particular may have a key role in the diagnosis of CAS/DVD, although they have advised that this needs confirmation in a larger and unselected group of children with speech difficulties (i.e. children other than those already suspected to have DVD/CAS).

In the current study, just over 80% of the children with speech difficulties had a difficulty with one or more measures of DDK performance, indicating that difficulties with DDK tasks were common amongst the group of children with speech difficulties, which supports the views of Crary (1993), Bradford & Dodd (1996) and Ozanne (1995; 2005). In Ozanne's study of one hundred children, aged 3;0-5;6 years, who were on a waiting list for speech and language therapy in local (non-specialised) community clinics, she found that 38% of the children were inaccurate on the DDK task and 35% produced slow DDK rates. These numbers are lower than the current study findings but Ozanne's cohort included children who had speech and/or language impairments (rather than only specific speech impairments) and who had not yet received any speech and language therapy intervention even at a local level. In comparison, sixteen of the children in the current study were attending for speech and language therapy at a specialist centre and therefore probably had more severe speech difficulties than most of the children in Ozanne's study.

The current study results question whether difficulties with DDK accuracy are unique to CAS/DVD as so many of the children (over 70%) with a range of different types and severity of speech difficulty had a difficulty with this measure. In the light of Murray et al.'s (2015) findings, it is important that further investigation of the diagnostic role of DDK in children with unselected speech impairments does take place to avoid a return to a position where DDK alone is used to diagnose CAS/DVD and/or to identify research study participants (Stackhouse, 1992; McCabe, Rosenthal and McLeod, 1998).

The findings from the current study indicate more support for DDK as a marker of speech difficulty in general, rather than being a specific marker of CAS/DVD. The inclusion criteria for this study were intentionally broad and therefore the children with speech difficulties could be regarded as an unselected group. For the main between-group study, no attempt was made to label or subdivide the children by the nature or severity of their speech difficulties. The only attempt to "classify" the children was made for the purpose of trying to find unifying characteristics shared by the children in each DDK profile and a modified linguistic approach (Dodd et al., 2002) was used. According to Dodd's criteria, only one child warranted further investigation for CAS/DVD. However, it is possible that a greater number of children would have been identified if more of the cohort had been tested on the DEAP Inconsistency Assessment (Dodd et al., 2002) and/or if a different approach to classification had been followed such as that used by Murray et al. (2015), where the children were classified against two sets of diagnostic criteria. This is particularly the case since sixteen of the forty children with speech difficulties were recruited at a specialist centre, the Nuffield Hearing and Speech Centre, known for its expertise in managing children with DVD. A proportion of these sixteen children had been described as having DVD or features of DVD in speech and language therapy reports either historically or currently. Despite the above caveats, DDK difficulties on at least one measure were shown by over 80% of the children, indicating that speech motor difficulties occur in children other than those with CAS/DVD. This view is supported by others. For example, by Waters (1995) from her study of a group of 12 children (aged 3; 8 - 4;10) with developmental phonological disorders who demonstrated poorer speech motor control in comparison to a group of typically-developing controls. Thoonen et al. (1999), have also reported that speech motor difficulties were seen in some of the group of children (aged 4 - 12 years) with a speech disorder of unknown origin, as well as in children with CAS and spastic dysarthria. Gibbon (1999) too identified "undifferentiated lingual gestures" in 12 of 17 children, aged 4 -12 years with articulation and phonological difficulties of unknown aetiology, which she interpreted as reflecting a speech motor constraint that was occurring as a result of either delayed or deviant control of independent regions of the tongue (tongue tip/blade, tongue body and lateral margins).

9.4.5 Summary of DDK and the nature of children's speech difficulties

The results from the current study support previous findings of heterogeneity within the population of children with speech difficulties (Dodd, 1995; Stackhouse & Wells, 1997). There was limited evidence of clearly defined subgroups, using either linguistic or psycholinguistic classification approaches. It is possible that more evidence for defined subgroups could be found in future studies involving a greater number of participants and including children across different age ranges, who are tested on the same tasks. The current findings did not support DDK being a diagnostic marker of DVD/CAS, rather it appeared to be a marker of speech difficulties in general.

9.6 Clinical Implications

9.6.1 Role of DDK in an assessment of speech difficulties

If DDK is a marker of speech difficulties in general, it could have an important role in screening and therefore should be included in initial assessments. However, for clinicians to be confident in interpreting assessment results, further normative data is required in order to clarify what should be expected for accuracy, consistency and rate at different ages, particularly in older children and adolescents. In addition, it would be useful to include a DDK task involving NW tri-syllables, in addition to a single NW repetition task, before discharge from speech and language therapy to ensure a child's speech difficulties have really resolved, and that there is low risk of associated lexical and literacy difficulties (Stackhouse et al., 2007). A child's ability to deal with novel NW targets taps a child's ability to assemble new motor programmes, a skill needed to rehearse and store new vocabulary. Children who are unable to assemble new motor programmes are at risk of having vocabulary problems because of their imprecise ("fuzzy") storage of lexical representations. In turn, this then causes problems for literacy development, and in particular for spelling. It is important to include tri-syllabic targets to challenge school-age children in particular in order to really know if they have hidden speech processing difficulties.

The findings from the current study involving children with speech difficulties indicate that motor skills for speech tasks should be assessed independently of motor skills for non-speech tasks. Murray et al., (2015) stress the importance of SLPs/SLTs carrying out an oral motor examination of any child seen for speech and language assessment, in order to rule out any structural deficits or functional impairments related to muscle strength and tone. They also advised that this oral motor assessment (OMA) should include diadochokinesis involving spoken targets. In contrast, the current study results indicate that the DDK assessment results should be interpreted independently of the OMA and in comparison to a single sound imitation task, in order to allow a comparison to be made between performance when producing isolated segments and performance on a sequence of speech sounds.

The findings from this study can contribute to the debate about the use of Non-Speech 0ral Motor Exercises (NSOMEs) in speech and language intervention of children's speech difficulties (Forrest, 2002; Bowen, 2005; Lof, 2008; 2010). Following extensive investigations in the literature through systematic reviews (e.g. McCauley et al., 2009; Lee and Gibbon, 2015), different views have emerged, though there appears little support to date for NSOMEs as an intervention. For example, McCauley et al. (2009) concluded:

"the existing research literature provides insufficient evidence to support or refute the use of NSOMEs" (p353).

In comparison, Lee and Gibbon (2015) concluded:

"Currently no strong evidence suggests that NSOMTs[8] are an effective treatment or an effective adjunctive treatment for children with developmental speech sound disorders" (p18).

The findings from the present study of a dissociation between oral motor skill and speech motor skill may help to explain why evidence to support the use of NSOMEs has been lacking. Working on oro-motor control through NSOMEs may improve oro-motor functioning but this will not necessarily transfer to speech motor functioning as different independent underlying systems are involved.

Findings from the current study have also provided useful information about two important aspects recommended by Crary (1993) that should be considered when utilising DDK tasks: (a) the selection of targets/stimuli and (b) the measurements and scoring methods which will be employed. The relevance of these to clinical practice is detailed below.

9.6.1.1 The selection of DDK targets/stimuli

Since the most demanding target for the clinical children as a group in the current study was a 3 syllable NW, it is recommended that a tri-syllable NW target (e.g. /ˈkudægn/ or /ˈpɒtɪkəʊk/

[8] NSOMTs refers to Non-Speech Oro-Motor Therapies

is included in a screening assessment. In contrast, the children were most accurate on 2 syllable RW targets and particularly on MONEY, which most of the children repeated accurately and at a rapid rate. Therefore, this would be a suitable target to provide a contrast to the 3 syllable NW target in a screening assessment or at least to use as a practice item. If more time is available, it would be advised to include one 2 syllable and one 3 syllable example from each of the RW, NW and SS conditions, following a practice item. This would enable a comparison to be made by both stimulus type and stimulus length. By including a combination of both challenging and less demanding tasks, a child's strengths as well as weaknesses can be identified (Stackhouse & Wells, 1997). Furthermore, it is more likely to ensure that a child's co-operation and motivation is maintained throughout the procedure.

9.6.1.2 The selection of DDK measures

Findings from the current study lead to the recommendation that children's performance on DDK tasks is measured separately for accuracy, consistency and rate, and that these are recorded independently, rather than by combining scores from each measure together to produce a composite DDK score. This is in contrast to the approach taken to DDK in the *Diagnostic Evaluation of Articulation and Phonology* (Dodd et al., 2002) for example, where DDK scores for (a) correct sound sequence, (b) intelligibility and (c) fluency are combined together. When this method was applied to a subset of the children's DDK results in the current study, children who had accuracy difficulties (in producing a correct sound sequence) were able to score within the normal range, provided they scored well on intelligibility and fluency. Thus, their difficulties with accuracy were masked by their better scores on the other two measures. By separating the scores into three different components (accuracy, consistency, rate), as in the current study, the children's individual strengths and weaknesses with DDK tasks are more transparent.

Measures of intelligibility and fluency as assessed on the DEAP (Dodd et al., 2002) were not examined for all children in the current study. However, based on the results from the subset of four, five and six year old children (n=23) where intelligibility and fluency were examined, they were not found to be sensitive measures. No child had a difficulty with the intelligibility measure and only one child had a difficulty with the fluency measure. In comparison, most of the children had a difficulty with producing a correct consonant sound sequence of PAT-A-CAKE, when repeating the target five or ten times (as advised for age). Therefore, of the three measures examined, accuracy was by far the most robust. This is in keeping with the current study findings where a greater proportion of the children with speech difficulties had a difficulty with DDK accuracy in comparison to DDK consistency or DDK rate.

9.6.1.3 Scoring for DDK accuracy

Two scoring methods for measuring DDK Accuracy were employed in the current study: (a) a binary scoring method (right vs. wrong) against set criteria and (b) Percentage Consonants Correct (PCC). A binary scoring method has been the main scoring method utilised in the DDK literature (e.g. Williams and Stackhouse, 2000; Dodd and McIntosh, 2008; Murray et al., 2015). In comparison, PCC has been used to provide a segmental analysis of connected speech samples (Shriberg & Kwiatkowski 1980; Shriberg et al., 1997) and of single word production (Dodd et al., 2002), and to measure change following intervention (Newbold et al., 2013).

The findings from the current study indicate that scoring DDK accuracy by PCC is the best method to reflect a child's ability to produce a consonant sound sequence correctly. In the main, the children with speech difficulties in the current study achieved higher scores on the PCC scoring method than on the binary scoring method. Furthermore, there was less evidence of individual variation amongst the children with speech difficulties on the PCC method compared to the binary scoring method. The binary scoring method was affected by factors other than a child's ability to produce the consonant sequence correctly, such as perseveration on a previous target or stopping before a run of five repetitions was complete. For example, stopping before a run of five repetitions is complete scores 0 point on the binary scoring method (see Chapter Three, 3.7.1.2), whereas on the PCC scoring method, any consonants not produced (e.g. the fifth repetition, if a child stopped after four repetitions), are removed, still allowing a maximum score to be recorded based on the repetitions that the child did produce (see Chapter Three, 3.7.1.3). Therefore, PCC scoring is a more sensitive measure of DDK accuracy. In addition, an advantage of using the PCC scoring method in this study was that it allowed close comparisons to be made between DDK accuracy and accuracy on other tasks, scored by the same method, such as single word naming.

9.6.1.4 Scoring for DDK consistency

Two scoring methods for measuring DDK Consistency were employed in the current study: (a) a binary scoring method scored against the child's own sound system rather than against an adult model and (b) a consistency strength rating to record the number of different versions produced in a run of five repetitions, in comparison to the child's first baseline production.

Both these scoring methods were utilised in the normative study of children aged 3-5 years by Williams and Stackhouse (2000) and were found to be helpful measures with young children, since they provided a method of scoring for consistency in comparison to the child's own still-developing speech sound system. A different scoring method to the consistency strength rating was utilised by Preston and Edwards (2009) and Preston and Koenig (2011) who summed the number of different versions of a DDK target produced by adolescents with residual speech difficulties over several trials. These studies involved adolescents, who could articulate all the segments in the DDK tasks and repeat the target accurately once, therefore there was no need to make comparisons against their own speech sound system as in the Williams and Stackhouse study (2000).

The results from the current study indicate that for children with speech difficulties who are unable to articulate all the segments in a DDK target, the binary scoring method is a useful measure since it allows a comparison to be made between a child's DDK accuracy (scored against an adult model) and their DDK consistency (scored in comparison to their own speech sound system). However, for children who can articulate all the segments in a DDK target and repeat the target accurately once, such a distinction is less important and a more meaningful and simpler measurement of consistency is a count of the number of different versions produced over a run of repetitions.

9.6.1.5 Scoring for DDK rate

In the current study, the duration of a run of five repetitions was recorded using Praat (Boersma & Weenink, 2001) from auditory digital files. DDK Rate was calculated in seconds per syllable/number of syllables per second. A similar method was employed to produce connected speech rate, based on a picture description task.

In the literature, DDK rates in normative studies have often been calculated using a stop watch (Fletcher, 1972; 1978; Canning & Rose, 1974; Robbins & Klee, 1987; Williams & Stackhouse, 2000) which is not as precise as using an objective measurement (Gadesmann & Miller, 2008; Murphy-Francis & Williams, 2012). Furthermore, the unit of measurement has varied e.g. Robbins and Klee (1987) reported rates based on the number of whole targets produced per second, whereas Haselager et al. (1991) and Yaruss & Logan (2002) reported rates based on the number of syllables produced per second.

In the current study, DDK rate was not found to correlate with any other speech processing measure, including connected speech rate, which questions its importance as a DDK measure, at least for children aged 4-7 years. Nevertheless, if a measurement of DDK rate is required in a clinical context (e.g. if the child's DDK production appears to be particularly slow), it is recommended that objective measurements are made from auditory digital files using freely downloadable software such as Praat (Boersma & Weenink, 2001) and that a calculation in syllables per second is made, as this allows for a direct comparison to be made with rates in imitated or spontaneous speech (Cohen et al., 1998).

9.6.1.6. Summary of findings for clinical practice

DDK can provide valuable information about a child's speech skills (rather than their oro-motor skills) and should be included routinely in speech assessments. Findings from the current study have provided recommendations for use of DDK in a clinical assessment. Ideally one 2 syllable and one 3 syllable RW, NW and SS targets should be included, following a practice item. However, if time is short, a minimum of one NW tri-syllabic target should be presented and repeated over a minimum of five repetitions. This number of repetitions was sufficient to detect difficulties in the current study, but as children mature, a greater number of repetitions may be required in order to fully tax their speech production system. Independent measures of accuracy, consistency and rate are recommended, but accuracy appears to be the most robust measure for children aged 4-7 years. Scoring accuracy using a PCC rather than a binary scoring method appears more sensitive. The best choice of scoring for consistency needs to be determined according to the child's presenting difficulties. For children, who cannot articulate all the target segments and cannot articulate the targets accurately once, selecting a scoring method which allow comparison with their own speech sound system is important. Rate did not correlate with any other speech processing measure in the current study but it may become more important as children get older. If it is used, objective measurement from auditory digital files using freely downloadable software will be more reliable than the use of a stop watch. Finally, although this was not an intervention study, the findings do support the view that oral motor and speech motor skills may be derived from two different systems which in turn suggests that the use of NSOMEs in clinical interventions may be limited in its impact on speech skills.

9.7 Strengths of the study

This study of relationships between DDK and other speech skills makes a novel contribution to the DDK literature in four main ways. First, its comprehensive design provides a systematic investigation of DDK skills in a group of children with speech difficulties (SD) in the age range 4-7 years recruited from both community and specialist settings. Second, the study involved not only a range of stimuli types and lengths, but also three different measures (accuracy, consistency and rate) and detailed scoring methods. Third, including data from age-matched typically-developing (TD) children has allowed group and individual performances of the children with SD to be compared to their TD peers. Fourth, the children's DDK accuracy, consistency and rate performance was related to their accuracy, consistency and rate performance on other speech processing measures. These four strengths combined has resulted in a better understanding of the nature of speech difficulties in children, and the role that DDK tasks might play in assessing children with and without speech difficulties.

9.8 Limitations of the study and future directions

In spite of the comprehensive nature of this study, there are a still a number of limiting factors related to the study design and methodology and these will now be discussed with advice for future directions.

9.8.1 Participants

The participant numbers are relatively small and this inevitably affects the statistical power. The findings of the study, and in particular the search for possible subgroups, should be verified in a larger population of children with speech difficulties. Furthermore, the distribution of children with speech difficulties by age and gender was not balanced evenly across the participant sample. In relation to age, more children were included in the age range 5;0-5;11 than in the other three age ranges (4;0-4;11, 6;0-6;11 and 7;0-7;11) and the numbers in the age range 7;0-7;11 were very small. In relation to gender, the ratio of boys to girls varied in each age group and the overall ratio of 3 boys to 1 girl is a higher ratio than might be expected overall in the population of children with speech difficulties. The participant numbers and distribution by age and gender were limited by the availability of suitable participants who met the inclusion criteria and by the willingness of parents and SLTs in the two NHS settings to take part in the study. A greater number of children with a more even distribution by age and gender may have been recruited if more NHS speech and language therapy services had been invited to participate in the study and this would have strengthened the findings. In any future study, a larger sample of participants, with a more even distribution by age and gender, should be included.

To meet the inclusion criteria all the children had to be receiving speech and language therapy intervention. However, children accepted for the study had received varying amounts of intervention, with some younger children just starting to receive intervention and other older children having received intervention over several years. In addition, some children in the primary care setting were receiving intervention from a speech and language therapy assistant (but under the direction of a SLT), whereas other children were receiving intervention directly from a SLT. Furthermore, a number of different treatment approaches and methods were being used with the children. One limitation of the current study is that it was not possible to control for the amount or type of therapy the children had received or for the agent delivering the intervention. All of these factors may have had an influence on the results. For example, some children may have practised rapid sequencing exercises as part of their therapy which could have improved their accuracy when tested on the DDK tasks. Furthermore, more evidence of subgroups may have been found if therapy related factors had been included as well as assessment results.

9.8.2 Assessment tasks

Although the full battery of speech assessments was administered to the children with speech difficulties attending the specialist setting, it was not possible to administer the DEAP Inconsistency Assessment (Dodd et al; 2002) to the children in the primary care setting, due to time constraints. This meant that correlations between DDK Consistency and consistency on the lexical task from the DEAP could only be calculated for a subset (40%) of the children. Furthermore, it meant that it was not possible to apply Dodd's linguistic classification to those children who had not carried out the Inconsistency Assessment and therefore this may have limited the identification of subgroups associated with the DDK profiles. In any further study involving DDK skills in relation to other speech skills, it would be important that the full test battery was administered to all the children.

Findings from the current study indicated that the sequenced movements subtest of the DEAP Oro-motor Assessment may not be as robust as the isolated movements subtest. In contrast, Bradford & Dodd (1996) found that the sequenced movements subtest was helpful in distinguishing between children with DVD and those with Inconsistent Phonological Disorder. However, the numbers of children in the DVD group were very small (n=5) and it is possible that these children had particular oro-motor difficulties affecting sequenced movements specifically. Nevertheless, the findings from the current study and the different results from the Bradford and Dodd (1996) study indicate that a more detailed oro-motor assessment, such as the OMA (Robbins & Klee, 1987) or the Oro-motor section of the *Nuffield Dyspraxia Programme Assessment* (Williams & Stephens, 2004) should be included in any future study, in order to assess the children's oro-motor skills in more detail. As reported under 9.6.1, an oral motor examination is important to rule out structural and functional oral deficits but an assessment of DDK involving spoken targets is not a part of this oral examination.

Connected speech data, from picture descriptions, was not collected from the typically-developing children in the current study, which meant that the connected speech rates of the children with speech difficulties could only be compared to published data in the literature, which had not always been sampled or recorded in the same way. In any future study, connected speech data should be ideally be collected from both typical and clinical participants. Furthermore, a more accurate measure of speaking rate is likely to be obtained from a conversational speech sample than from a picture description task and therefore this should be included in any future study.

9.8.3 Procedure

Although there was a planned procedural order (as described in Chapter Three, 3.6.2 and 3.6.3) for administering the tasks, changes were made for some of the children (particularly those in the youngest age group) in order to ensure their interest and motivation. Although this ensured the children gave their co-operation for the tasks, the change to the planned order may have affected the results. In addition, the method used to help the children know when they had produced five repetitions on the DDK tasks was not consistent for all the children. The intention was to use a 'marking off' procedure with the tester holding up her right hand and revealing a finger or thumb for each repetition and instructing the child that when they could see all four fingers and the thumb they had produced the required number of repetitions. Since this method was not successful with some children, a different method was then employed involving a tick chart, as described in Williams & Stackhouse (2000). This inconsistency in the methodology may have affected the results to some extent. For example, the children's DDK rate may have been affected by this change and/or they may have been more/less likely to stop before the run was complete, according to their response to each method. As in any study, changes to the planned procedure and method are not advised. However, given the young age of the participants, some flexibility was necessary to ensure the children co-operated as much as possible.

9.9 Conclusion

DDK skills are commonly assessed by SLTs in clinical practice but their contribution to understanding the nature of an individual child's speech difficulties has often been unclear. Findings from this study indicate that DDK tasks tap articulatory rather than oro-motor skill and involve some aspect of higher level lexical processing. DDK however is not a single skill but comprises the interaction of accuracy, rate and consistency, where accuracy and consistency are more sensitive than rate when investigating young children's speech development. Difficulties in performing DDK tasks were common in the 4-7 year old children with speech difficulties compared to the typical children but were a marker of speech impairment in general rather than being associated with a specific diagnosis such as DVD. Further, although specific DDK profiles of performance emerged within the clinical group, there was no linguistic or psycholinguistic evidence for discrete subgroups of children's speech difficulties but further investigation of a larger sample is needed to confirm this. The comprehensive and systematic testing of DDK in this study has allowed recommendations for what to include in a screening assessment of DDK to be made and the evidence suggests that DDK tasks are a valuable tool to include in an assessment of children referred to speech and language therapy services, as well as in a discharge protocol following intervention.

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Appendix 3.1 NHS Ethical Approval

NHS

National Research Ethics Service

Central London REC 1
Level 7N019, Maternity Block
Northwick Park Hospital
Watford Road
Harrow
Middx
HA1 3UJ

Telephone: 020 8869 3775
Facsimile: 020 8869 5222

08 July 2010

Mrs Pamela M. Williams
Consultant Speech and Language Therapist
Royal Free Hospital NHS Trust
Nuffield Hearing and Speech Centre
RNTNE Hospital 330 Gray's Inn Road
London UK
WC1X 8DA

Dear Mrs Williams

Study Title:	**Diadochokinetic profiles of children with speech difficulties and the relationship between these and other speech processing measures.**
REC reference number:	**10/H0718/39**
Protocol number:	**N/A**

The Research Ethics Committee reviewed the above application at the meeting held on 30 June 2010. Thank you for attending to discuss the study.

Ethical opinion

a. The Committee asked which tests you are planning to carry out under routine care. You explained that this depends on the routine care the child is getting and that speech and language will use sub tests from it.
b. You were asked if you it is necessary to repeat these tests if they are already being carried out. You explained that they would repeat this every three months only.
c. The Committee asked if you considered these tests too ambitious for four year olds to carry out. You replied that most sessions are one hour and they consist of rapid changes of activity to keep the child interested, the children will be offered awards a lot praise and encouragement. You added that they may do an additional session if required.
d. The Committee asked if the consent was separate for audio and the video and what effect this will have on the research. You said they would like both but audio is best however, with the video you are able to see the child struggling to get his/her mouth into play.
e. Member asked if you can get both into the study will you be able to consolidate consent. You said that you would.
f. The Committee asked if the audio/video will be put onto a laptop or the Royal Free server. You explained that it is transferred on NHS premises to her laptop for one day only to collect data and analysis, you added that as this is time consuming you will need to carry out most of the work at home. You also pointed out that this information will be encrypted.
g. The Committee informed Mrs Williams that they thought the GP letter was unnecessary, and you agreed not to use one.

The members of the Committee present gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

The Committee has not yet been notified of the outcome of any site-specific assessment (SSA) for the non-NHS research site(s) taking part in this study. The favourable opinion does not therefore apply to any non-NHS site at present. I will write to you again as soon as one Research Ethics Committee has notified the outcome of a SSA. In the meantime no study procedures should be initiated at non-NHS sites.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned</u>.

For NHS research sites only, management permission for research ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk. Where the only involvement of the NHS organisation is as a Participant Identification Centre, management permission for research is not required but the R&D office should be notified of the study. Guidance should be sought from the R&D office where necessary.

Sponsors are not required to notify the Committee of approvals from host organisations.

It is responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The documents reviewed and approved at the meeting were:

Document	*Version*	*Date*
Investigator CV		
Protocol	1	11 May 2010
CV Supervisor		
REC application		13 May 2010
Covering Letter		26 May 2010
GP/Consultant Information Sheets	1	11 May 2010
Participant Information Sheet: The relationship between performance of rapid speech repetition tasks and other speech and listening tasks.	1	11 May 2010
Participant Consent Form		
Participants Infromation Sheet for Children	1	11 May 2010
Children's assent form	1	11 May 2010
Evidence of insurance or indemnity		26 May 2010
Referees or other scientific critique report		

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Service website > After Review

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nres.npsa.nhs.uk.

10/H0718/39	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project

Yours sincerely

PP JKidd

Dr John Keen
Chair

Email: Julie.kidd@nwlh.nhs.uk

Enclosures: *List of names and professions of members who were present at the meeting and those who submitted written comments*
"After ethical review – guidance for researchers"

Copy to: *Lauren Smaller,*
University of Sheffield
Academic Services
New Spring House
231 Glossop Road
S10 2GW

Appendix 3.2 Research and Development Approval: Royal Free Hospitals NHS Trust

Study Title: Diadochokinetic profiles of children with speech difficulties and the relationship between these and other speech processing measures
Reference: URMS 128718 R&D 8094

SCHEDULE 1

STUDY PROTOCOL

Note 1: The Protocol must set out the objectives, design, methodology, statistical and organisational arrangements.

Note 2: The Parties should check that there are no conflicts between Agreement clauses and Protocol. Any conflicts that are identified must be resolved prior to signing this Agreement.

Note 3: Should there be any inconsistency between the Protocol and the other terms of this Agreement, or any document incorporated therein, clause 2.2 of this Agreement shall apply.

Summary of Management Arrangements

Funder(s)....................N/A
Sponsor(s).... University of Sheffield (State if co-sponsorship or joint sponsorship)
Chief Investigator for the Study...Pamela Williams............Employer...Royal Free Hampstead NHS Trust, Pond Street, London NW3 2QG
Principal Investigator...Pamela Williams.........Employer.........Royal Free Hampstead NHS Trust, Pond Street, London NW3 2QG
Study coordinating organisation.........Royal Free Hampstead NHS Trust, Pond Street, London NW3 2QG..................
Others organisations (specify)

Number of Participants to be recruited at the Site ....20...........
Number of samples/ records to be provided by the Site......20..........

Timelines:

Milestone	Target date
Provision of materials for Ethics Committee submission	May 2010
Ethics Committee submission	Meeting: 30.06.10 Approved: July 2010
First Participant recruited	November 2010
Last Participant recruited	November 2012
[Insert other milestones as applicable]	Submit Ph D July 2013

Protocol attached

PA

19.2 The Parties may agree to override clause 19.1.1, 19.1.2 and 19.1.3 and nominate the English and Welsh or Scottish or Northern Irish laws and court jurisdiction to apply to this Agreement irrespective of the location of the Site or Sites. Any such nomination must be in writing and signed by all Parties.

SIGN OFF

Signed by the duly authorised representatives of the Parties on the date stated at the beginning of this Agreement

SIGNED ON BEHALF OF THE SPONSOR

Graham Sykes
Research and Innovation
Opportunities Manager
University of Sheffield

20/12/10

Name	Position	Signature	Date

SIGNED ON BEHALF OF NHS ORGANISATION

17/1/11

Name	Position	Signature	Date

Professor Stephen Powis
Medical Director
The Royal Free Hampstead NHS Trust

Appendix 3.3 Research and Development Approval: Herts Community NHS Trust

Hertfordshire Community NHS
NHS Trust

Peace Children's Centre
Peace Prospect
Watford
Herts
WD17 3EW

Tel: 01923 470662
Fax: 01923 470618

mark.whiting@hchs.nhs.uk

Date: Friday 27th April 2012

To: Ms P Williams,
Consultant Speech and Language
Therapist/Team Manager
Nuffield Hearing and Speech Centre
RNTNE Hospital
330 Gray's Inn Road
London
WC1X 8DA

Dear Pam,

Re: **Diadochokinetic profiles of children with speech difficulties and the relationship between these and other speech processing measures.**

I am writing to you formally on behalf of Hertfordshire Community NHS Trust in order to confirm research governance approval for the above proposal. I note that you have already received a favourable opinion to your research proposal from the Central London (REC1) Research Ethics Committee and I have a copy of that approval on file.

I note that your proposed study, which is being undertaken as part of your PhD study at the University of Sheffield, will involve the recruitment of a total of 40 children aged 4 - 7 years with speech difficulties and that Hertfordshire will provide a sub-sample of this total study group. I note that you intend to appoint a local investigator who will not carry out any of the research but will assist in the recruitment of local children to the study. Su Johnston, HCT Head of Children's Speech and Language Therapy will facilitate this aspect of your study. Su will also liaise with you in relation to the provision of an honorary contract. Su has also signed section 23 of the IRAS documentation for you and I enclose a copy for your records.

I confirm that I have received a copy of your enhanced Criminal Records Bureau documentation.

As part of this approval to proceed, you will be required to:

- Provide information to HCT, on request, as part of the Trust annual research monitoring process;
- Provide HCT with a summary of the research once it is completed;
- Inform HCT about all publications relating to the research; and
- Acknowledge HCT in all publications relating to the research.

Hertfordshire Community NHS Trust looks forward to working with you on this project.

Please do not hesitate to contact me if you require any further information.

Kind regards,

Mark Whiting,
Consultant Nurse,
Children's Community and Specialist Nursing

Appendix 3.4: Targets for DDK Tasks

Practice (P) or Test (T)	Real Word Target	Non-Word target	Syllable Sequence Target
P	potty	[ˈpetə]	[ˈpəˈtə]
P	motorbike	[ˈmɑʊtɪbeɪk]	[ˈməˈtəˈbə]
T	party	[ˈputə]	[ˈpəˈtə]
T	cardigan	[ˈkudægn]	[ˈkəˈdəˈgə]
T	patacake	[ˈpɒtɪkəʊk]	[ˈpəˈtəˈkə]
T	money	[ˈmɪnə]	[ˈməˈnə]
T	letterbox	[ˈlʌtɪbæks]	[ˈləˈtəˈbə]
T	telephone	[ˈtɒləfaɪn]	[ˈtəˈləˈfə]
T	digger	[ˈdægɪ]	[ˈdəˈgə]
T	coffee	[ˈkɪfə]	[ˈkəˈfə]

Appendix 3.5: Distribution of consonant segments on DDK tasks

Consonant segments	C1	C2	C3
p-t	p	t	
k-d-g	k	d	g
p-t-k	p	t	k
m-n	m	n	
l-t-b	l	t	b
d-g	d	g	
t-l-f	t	l	f
k-f	k	f	

Key: C1=First onset syllable consonant, C2=Second onset syllable consonant, C3=Third onset syllable consonant.

Appendix 3.6: Created Mispronunciations for Mispronunciation Detection Task.

Key: Con.=consonant; persev.=persevartion; transp.=transposition.

Target	Practice or Test	Real word	Persev. Of Con.	Transp. Of Con.	Vowel change	Con. feature Change
BABY	Practice	Y				
['bɛɪsɪ]						Y
LOLLY	Practice	Y				
['lɒpɪ]						Y
TIGER	Practice	Y				
['waɪgə]						Y
YELLOW	Practice	Y				
['jɛkəʊ]						Y
POTTY	Practice	Y				
['nɒtɪ]						Y
SEESAW	Practice	Y				
['si'bɔ]						Y
JELLY	Practice	Y				
['pɛlɪ]						Y
COOKER	Practice	Y				
['kʊzə]						Y
PATACAKE	Test	Y				
['pætəteɪk]			Y			
['pækəteɪk]				Y		
['pækəkeɪk]			Y			
['pætəkəʊk]					Y	
['pɒtəkeɪk]					Y	

Target	Practice or Test	Real word	Persev. Of Con.	Transp. Of Con.	Vowel change	Con. feature change
CARDIGAN	Test	Y				
['kagɪdən]				Y		
['kagɪgən]			Y			
['kadɪdən]				Y		
['kudɪgən]					Y	
['kɜdɪgən]					Y	
['keɪdɪgən]					Y	
TELEPHONE	Test	Y				
['tɛlələʊn]			Y			
['tɛfələʊn]				Y		
['tɛfəfəʊn]			Y			
['tɒləfəʊn]					Y	
['tɛləfaɪn]					Y	
LETTERBOX	Test	Y				
['lɛtətɒks]			Y			
['lɛbətɒks]				Y		
['lɛbəbɒks]			Y			
['lʌtəbɒks]					Y	
['lɛtəbæks]					Y	
MONEY	Test	Y				
['nʌnɪ]			Y			
['nʌmɪ]				Y		
['mʌlɪ]						Y
['mænɪ]					Y	

Target	**Practice or Test**	**Real word**	**Persev. Of Con.**	**Transp. Of Con.**	**Vowel change**	**Con. feature change**
PARTY	Test	Y				
['pɑpɪ]			Y			
['tɑpɪ]				Y		
['bɑtɪ]			Y			Y
['putɪ]					Y	
COFFEE	Test	Y				
['fɒfɪ]			Y			
['fɛkɪ]				Y+ V change		
['gɒfɪ]						Y
DIGGER	Test	Y				
['dɪdə]			Y			
['gɪdə]				Y		
['dɪŋə]						Y
['dʌgə]					Y	

Appendix 3.7: Stimuli for Vocabulary Selection Task on Mispronunciation Detection Task

Target	**Semantic distractor**	**Same onset distractor**	**Same syllable structure distractor**
party	biscuit	parachute	seesaw
money	paper	motorbike	yellow
digger	tractor	dinosaur	tiger
coffee	fizzy (drink)	computer	lolly
patacake	glove	potty	buttercup
cardigan	pyjamas	cooker	roundabout
telephone	television	toilet	sellotape
letterbox	dustbin	ladder	caravan

Appendix 3.8: Instructions for administering the DDK Tasks

Real words

We're going to look at some pictures (again). I'm going to say the name of a picture and I want you to say it after me. Listen carefully and try to say it just like I do. Good. Now I want you to say that word five times as fast as you can. To help you know how many times you have said the word, I'm going to put up my fingers and thumb (demonstrate) and when they are all up you will have said it five times. I'll say go when it's time to start. I'm going to time you with this stopwatch to check how fast you are.

Non-words

I'm going to say some made up nonsense words that you won't have heard before. I want you to say them after me. Listen carefully and try to say them just like I do. Good. Now I want you to say that five times as fast as you can. To help you know how many times you have said the word, I'm going to put up my fingers and thumb (demonstrate) and when they are all up you will have said it five times. I'll say go when it's time to start. I'm going to time you with this stopwatch to check how fast you are.

Non-words for younger children

Now I want you to meet my friend monkey, who has some special monkey words, that you won't have heard before. Monkey will tell you a special word and then ask you to say it. Listen carefully and try to say them just like the monkey. Good. Now I want you to say that five times as fast as you can. To help you know how many times you have said the word, I'm going to put up my fingers and thumb (demonstrate) and when they are all up you will have said it five times. I'll say go when it's time to start. I'm going to time you with this stopwatch to check how fast you are.

Syllable-sequences

I'm going to say some sounds and I want you to say them after me. Listen carefully and try to say them just like I do. Good. Now I want you to say that five times as fast as you can. To help you know how many times you have said the word, I'm going to put up my fingers and thumb (demonstrate) and when they are all up you will have said it five times. I'll say go when it's time to start. I'm going to time you with this stopwatch to check how fast you are.

Appendix 3.9 Scoring example DDK Accuracy and DDK Consistency RH5

Key: Acc=Accuracy; Cons=Consistency.

RW Target	1X	Score	1	2	3	4	5	Acc	Cons	Cons Strength Rating
party	ˈpɑʔi	0	ˈpɑki 2	ˈpɑki 2	ˈpɑki 2	ˈpɑki 2	ˈpɑki 2	0	0	2
cardigan	ˈkɑgɪgn̩	0	ˈkɑgɪgn̩ 1	ˈkɑʔɪgn̩ 2	ˈkɑgɪgn̩ 1	ˈkɑgɪgn̩ 1	ˈkɑgɪgn̩ 1	0	0	2
patacake	ˈpækəkeɪk	0	ˈpækəkeɪʔ 1	ˈpækəkeɪʔ 1	ˈpækəkeɪʔ 1	ˈpʌkəkeɪʔ 1	ˈpʌkə-kəkeɪk 2	0	0	2
money	ˈmʌŋi	0	ˈmʌŋi 1	ˈmʌŋi 1	ˈmʌŋi 1	ˈmʌŋi 1	ˈmʌŋi 1	0	1	1
letterbox	ˈjekəbɒks	0	ˈjekəbɒk 1	ˈjekəbɒk 1	ˈjekəbɒk 1	ˈjekəbɒk 1	ˈjeʔəbɒk 2	0	0	2
telephone	ˈkeɪjəfəʊn	0	ˈkeɪjəfəʊn 1	ˈkeɪjəfəʊn 1	ˈkeɪjəfəʊn 1	ˈkeɪjəfəʊn 1	ˈkeɪjəfəʊn 1	0	1	1
digger	ˈgɪgə	0	ˈgɪgə 1	ˈgɪgə 1	ˈgɪgə 1	ˈgɪgə 1	ˈgɪgə 1	0	1	1
coffee	ˈkɒfi	1	ˈkɒfi 1	ˈkɒfi 1	ˈkɒfi 1	ˈkɒfi 1	ˈkɒfi 1	1	1	1
RW 2 sylable		1					RW 2 syllable	1	3	
RW 3 syllable		0					RW 3 syllable	0	1	
Totals		1/8					Totals	1/8	4/8	
							Ratings			1:4 ; 2:4

NW Target	**1X**	**Score**	**1**	**2**	**3**	**4**	**5**	**Acc**	**Cons**	**Cons Strength Rating**
putə	ˈpukə	0	ˈpukə 1	ˈpukə 1	ˈpukə 1	ˈpukə 1	ˈpukə 1	0	1	1
kudægn	ˈkugɪgn̩	0	ˈkugɪgn̩ 1	ˈkugɪgn̩ 1	ˈkugɪgn̩ 1	ˈkugɪgn̩ 1	ˈkugɪgn̩ 1	0	1	1
pɒtɪkəʊk	ˈpɒkɪkəʊk	0	ˈpɒkɪkəʊk 1	ˈpɒkɪkəʊk 1	ˈpɒkɪkəʊk 1	ˈpɒkɪkəʊk 1	ˈpɒkɪkəʊk 1	0	1	1
mɪnə	ˈmɪŋə	0	ˈmɪŋə 1	ˈmɪŋə 1	ˈmɪŋə 1	ˈmɪjə 2	ˈmɪjə 2	0	0	2
lʌtɪbæks	ˈjʌkɪbæks	0	ˈjʌkɪbæk 1	ˈjʌkɪbæk 1	ˈjʌkɪbæk 1	ˈjʌkɪbæk 1	ˈjʌkɪbæk 1	0	1	1
tɒləfaɪn	ˈkɒləfaɪn	0	ˈkɒləfaɪn 1	ˈkɒləfaɪn 1	ˈkɒləfaɪn 1	ˈkɒləfaɪn 1	ˈkɒləfaɪn 1	0	1	1
dægɪ	ˈgægɪ	0	ˈgægɪ 1	ˈgægɪ 1	ˈgægɪ 1	ˈgægɪ 1	ˈgægɪ 1	0	1	1
kɪfə	ˈkifə	1	ˈkɪkə 2	ˈkɪkə 2	ˈkɪkə 2	ˈkɪkə2	ˈkɪkə2	0	0	2
NW 2 syll		1					2 syll	0	2	
NW 3 syll		0					3 syll	0	4	
Totals		0/8					Totals	0/8	6/8	
							Ratings			1:6 2:2

SS Target	**1X**	**Score**	**1**	**2**	**3**	**4**	**5**	**Acc**	**Cons**	**Cons Strength Rating**
pətə	ˈpəˈkə	0	ˈpəkə 1	ˈpəkə 1	ˈpəkə 1	ˈpəkə 1		0	0	0
kədəgə	ˈkəgəgə	0	ˈkəgəgə 1	ˈkʊgəgə 1	ˈkʊgəgə 1	ˈkʊgəgəʊ 1		0	0	0
pətəkə	ˈpəkəkə	0	ˈpəkəkə 1	ˈpəkəkə 1	ˈpəkəkə 1	ˈkʊkəbə 2	ˈkʊkəbə 2	0	0	2
mənə	ˈməŋə	0	ˈməŋə 1	ˈməŋə 1	ˈməŋə 1	ˈməŋə 1	ˈməŋə 1	0	1	1
lətəbə	ˈlʊkəbə	0	ˈlʊkəbə 1	ˈlʊkəbə 1	ˈlʊkəbə 1	ˈlʊkəwə 1	ˈlʊkəwə 1	0	0	2
tələfə	ˈkələfə	0	ˈkələfə 1	ˈkələfə 1	ˈkələfə 1	ˈkələfə 1	ˈkələfə 1	0	1	1
dəgə	ˈgəgə	0	ˈgəgə 1	ˈgɪgə 1	ˈgɪgə 1	ˈgɪgə 1	ˈgɪgə 1	0	1	1
kəfə	ˈkʊfə	1	ˈkʊfə 1	ˈkʊfə 1	ˈkɪkə 2	ˈkɪkə 2	ˈkɪkə 2	0	0	2
SS 2 syll		1					2 syll	0	2	
SS 3 syll		0					3 syll	0	1	
Totals		1/8					Totals	0/8	3/8	
							Ratings			0:2; 1:3; 2:3

Appendix 3.10 Score sheet example PCC

Child: ....CS5.......................... : Accuracy X 1 & X 5 repetitions

Target RW	X1 No Onset Syll Cs	Total cons elicited	X1 Cons correct	X5 No onset syll. Cs.	Cons not elicited	Total cons elicited	Cons in error	X5 Cons correct
party	2	2	2	10		10		10
money	2	2	2	10		10		10
digger	2	2	1	10		10	6	4
coffee	2	2	1	10		10	9	1
Total cons.	8	8	6	40		40		25
PCC 2 syll			75%					**63%**
cardigan	3	1	1	15	6	9		4
patacake	3	2	2	15	3	12		7
letterbox	3	2	0	15	9	6		0
telephone	3	2	2	15	9	6		4
Totals	12	7	5	60	27	33		15
PCC 3 syll			71%					**45%**
PCC totals			73%					**54%**
Target NW								
putə	2	2	1	10		10	9	1
mɪnə	2	2	1	10		10	5	5
dægɪ	2	2	1	10		8	8	0
kɪfə	2	2	0	10		10	10	0
Total cons	8	8	3	40		38	32	6
PCC 2syll			38%					16%
kudægn	3	3	1	15	4	11	6	5
pɒtɪkəʊk	3	2	1	15	5	10	3	7
lʌtɪbæks	3	2	1	15	8	7	7	0
tɒləfaɪn	3	2	1	15	5	10	4	6
Total cons	12	9	4	60		38	20	18
PCC 3 syll			44%					47%
PCC totals			41%					32%
Target SS								
pətə	2	2	1	10	6	4	0	4
mənə	2	2	1	10	2	8	4	4
dəgə	2	2	0	10	4	6	6	0
kəfə	2	2	1	10	10	0	0	0
Total cons	8	8	3	40	22	18	10	8
PCC 2 sylls			38%					44%
kədəgə	3	3	2	15	7	8	7	1
pətəkə	3	2	0	15	7	8	4	4
lətəbə	3	2	0	15	7	8	8	0
tələfə	3	3	1	15	8	7	7	0
Total cons	12	10	3	60	28	31	26	5
PCC 3 syll			30%					16%
PCC totals			34%					30%

Appendix 3.11 Score Sheet Example DDK Rate (Praat) for SC7

RW Target	RW Timed response	NW target	NW Timed response	SS Target	SS Timed response
party	3.746873	ˈputə	2.553709 (4 reps)	ˈpəˈtə	2.800285
cardigan	8.298630	ˈkudægn	8.47606	ˈkəˈdəˈgə	7.153531
patacake	4.440738	ˈpɒtɪkəʊk	6.117366	ˈpəˈtəˈkə	1st attempt: 3.970897 (4 reps, 1 syllable omitted) 2nd attempt: 5.432248
money	3.367560	ˈmɪnə	2.584402	ˈməˈnə	3.159885
letterbox	5.088346	ˈlʌtɪbæks	Incl=8.505587 Excl=6.731496	ˈləˈtəˈbə	4.246334
telephone	3.663609 (4 reps)	ˈtɒləfaɪn	4.910978	ˈtəˈləˈfə	5.784196
digger	3.349057	ˈdægɪ	3.173720	ˈdəˈgə	2.578405
coffee	2.525670 (4 reps)	ˈkɪfə	2.946587	ˈkəˈfə	3.075723

Appendix 3.12 Score Sheet Example Connected Speech Rate (Praat) for AG6

Sampling Mode	**Utterance**	**No. of Syllables Produced**	**Utterance Duration**	**Duration Per Syllable**
DEAP Connected Speech Pictures	1. He got yellow tummy.	6	1.650331	.275
	2. Carrying a snake on his shoulder.	9	3.916190	.435
	3. Tomato and it's got leaf.	7	3.443393	.492
LDA What's wrong Pictures	4. He's wearing a wellie.	6	1.935651	.323
	5. Mum cleaning her hair with vacuum cleaner.	10	3.957650	.396
	6. Somebody digging end of shovel.	9	4.115956	.457
	Mean			.396

Appendix 4.1 Clinical children: Single repetition raw accuracy scores (binary) by stimulus condition

Key: Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words /8	Non words /8	Syllable sequences /8	Combined total /24
AJ4	41	5.00	5.00	6.00	16.00
DC4	42	3.00	1.00	1.00	5.00
EW4	43	.00	2.00		
JJ4	44	7.00	5.00	4.00	16.00
LR4	45	6.00	5.00	8.00	19.00
MP4	46	4.00	6.00	6.00	16.00
PG4	47	1.00	1.00	1.00	3.00
SB4	48	3.00	2.00	3.00	8.00
TB4	49	8.00	7.00	7.00	22.00
TH4	50	2.00	2.00	2.00	6.00
ChS5	51	8.00	8.00	8.00	24.00
CS5	52	2.00	.00	.00	2.00
DG5	53	7.00	6.00	6.00	19.00
EN5	54	7.00	8.00	8.00	23.00
IF5	55	8.00	7.00	6.00	21.00
IT5	56	4.00	4.00	5.00	13.00
JB5	57	5.00	5.00	6.00	16.00
JC5	58	8.00	7.00	8.00	23.00
JK5	59	2.00	2.00	4.00	8.00
KK5	60	6.00	4.00	4.00	14.00
KW5	61	4.00	6.00	6.00	16.00
LS5	62	1.00	5.00	6.00	12.00
OB5	63	4.00	7.00	5.00	16.00
OP5	64	4.00	4.00	4.00	12.00
PBS5	65	8.00	7.00	8.00	23.00
RB5	66	6.00	6.00	7.00	19.00
RH5	67	1.00	1.00	1.00	3.00
RW5	68	8.00	8.00	8.00	24.00
SH5	69	8.00	7.00	8.00	23.00
TN5	70	8.00	8.00	6.00	22.00
AG6	71	4.00	4.00	3.00	11.00
CC6	72	7.00	6.00	7.00	20.00
EC6	73	4.00	6.00	6.00	16.00
HL6	74	4.00	4.00	4.00	12.00
HM6	75	8.00	8.00	8.00	24.00
KH6	76	8.00	8.00	8.00	24.00
TC6	77	4.00	6.00	5.00	15.00
TM6	78	5.00	5.00	4.00	14.00
JC7	79	8.00	8.00	7.00	23.00
SC7	80	7.00	8.00	7.00	22.00

Appendix 4.2 Clinical children: Single repetition raw accuracy scores (PCC) by stimulus condition and mean PCC across the conditions.

Key: PCC = percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words	Non words	Syllable sequences	Mean PCC
AJ4	41	92.00	92.00	92.00	92.00
DC4	42	44.00	38.00	36.00	39.33
EW4	43	44.00	77.00		
JJ4	44	96.00	88.00	82.00	88.67
LR4	45	94.00	78.00	100.00	90.67
MP4	46	69.00	84.00	84.00	79.00
PG4	47	46.00	46.00	53.00	48.33
SB4	48	54.00	57.00	67.00	59.33
TB4	49	100.00	96.00	92.00	96.00
TH4	50	71.00	78.00	70.00	73.00
ChS5	51	100.00	100.00	100.00	100.00
CS5	52	73.00	41.00	34.00	49.33
DG5	53	95.00	95.00	95.00	95.00
EN5	54	96.00	100.00	100.00	98.67
IF5	55	100.00	96.00	92.00	96.00
IT5	56	71.00	67.00	71.00	69.67
JB5	57	88.00	84.00	92.00	88.00
JC5	58	100.00	100.00	100.00	100.00
JK5	59	67.00	69.00	78.00	71.33
KK5	60	71.00	75.00	73.00	73.00
KW5	61	79.00	90.00	90.00	86.33
LS5	62	44.00	86.00	86.00	72.00
OB5	63	78.00	94.00	88.00	86.67
OP5	64	69.00	73.00	79.00	73.67
PBS5	65	100.00	96.00	100.00	98.67
RB5	66	96.00	84.00	88.00	89.33
RH5	67	57.00	61.00	65.00	61.00
RW5	68	100.00	100.00	100.00	100.00
SH5	69	100.00	94.00	100.00	98.00
TN5	70	100.00	100.00	100.00	100.00
AG6	71	78.00	75.00	71.00	74.67
CC6	72	96.00	90.00	96.00	94.00
EC6	73	73.00	84.00	86.00	81.00
HL6	74	75.00	79.00	79.00	77.67
HM6	75	100.00	100.00	100.00	100.00
KH6	76	100.00	100.00	100.00	100.00
TC6	77	81.00	94.00	88.00	87.67
TM6	78	88.00	88.00	82.00	86.00
JC7	79	100.00	100.00	96.00	98.67
SC7	80	100.00	100.00	100.00	100.00

Appendix 4.3 Typical children: Single repetition raw accuracy scores (binary) by stimulus condition (/8) and combined mean totals (/24).

Key: Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words /8	Non words /8	Syllable sequences /8	Combined total /24
AL4	1	8.00	8.00	8.00	24.00
An4	2	8.00	8.00	8.00	24.00
Ann4	3	8.00	8.00	8.00	24.00
Bel4	4	8.00	8.00	8.00	24.00
BN4	5	8.00	8.00	8.00	24.00
Is4	6	8.00	6.00	8.00	22.00
Ja4	7	8.00	8.00	8.00	24.00
Jo4	8	8.00	7.00	8.00	23.00
Ma4	9	8.00	8.00	8.00	24.00
Ni4	10	8.00	7.00	8.00	23.00
Re4	11	7.00	8.00	7.00	22.00
AB5	12	6.00	6.00	5.00	17.00
AL5	13	6.00	8.00	8.00	22.00
Anl5	14	8.00	8.00	8.00	24.00
Ao5	15	8.00	7.00	8.00	23.00
CE5	16	8.00	8.00	8.00	24.00
Da5	17	8.00	8.00	8.00	24.00
EL5	18	8.00	8.00	8.00	24.00
Ha5	19	7.00	7.00	6.00	20.00
Is5	20	8.00	8.00	8.00	24.00
Lo5	21	8.00	8.00	6.00	22.00
Ra5	22	8.00	8.00	8.00	24.00
Rh5	23	8.00			
Ro5	24	6.00	7.00	7.00	20.00
SO5	25	8.00	8.00	8.00	24.00
Ta5	26	8.00	8.00	8.00	24.00
Xa5	27	8.00	8.00	8.00	24.00
Za5	28	8.00	8.00	8.00	24.00
CM16	29	8.00	8.00	8.00	24.00
CM26	30	8.00	8.00	8.00	24.00
DK6	31	8.00	8.00	8.00	24.00
HM6	32	8.00	8.00	8.00	24.00
JM6	33	8.00	8.00	8.00	24.00
KB6	34	8.00	8.00	8.00	24.00
NB6	35	8.00	8.00	8.00	24.00
RS6	36	8.00	8.00	8.00	24.00
SB6	37	8.00	8.00	8.00	24.00
DQ7	38	8.00	8.00	8.00	24.00
DR7	39	8.00	8.00	8.00	24.00
EO7	40	8.00	8.00	8.00	24.00

Appendix 4.4 Typical children: Single repetition raw accuracy scores (PCC) by stimulus condition and mean PCC across the conditions.

Key: PCC = percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words	Non words	Syllable sequences	Mean PCC
AL4	1	100.00	100.00	100.00	100.00
An4	2	100.00	100.00	100.00	100.00
Ann4	3	100.00	100.00	100.00	100.00
Bel4	4	100.00	100.00	100.00	100.00
BN4	5	100.00	100.00	100.00	100.00
Is4	6	100.00	84.00	100.00	94.67
Ja4	7	100.00	100.00	100.00	100.00
Jo4	8	100.00	96.00	100.00	98.67
Ma4	9	100.00	100.00	100.00	100.00
Ni4	10	100.00	96.00	100.00	98.67
Re4	11	96.00	100.00	96.00	97.33
AB5	12	92.00	92.00	78.00	87.33
AL5	13	92.00	100.00	100.00	97.33
Anl5	14	100.00	100.00	100.00	100.00
Ao5	15	100.00	96.00	100.00	98.67
CE5	16	100.00	100.00	100.00	100.00
Da5	17	100.00	100.00	100.00	100.00
EL5	18	100.00	100.00	100.00	100.00
Ha5	19	96.00	92.00	92.00	93.33
Is5	20	100.00	100.00	100.00	100.00
Lo5	21	100.00	100.00	90.00	96.67
Ra5	22	100.00	100.00	100.00	100.00
Rh5	23	100.00			
Ro5	24	88.00	100.00	100.00	96.00
SO5	25	100.00	100.00	100.00	100.00
Ta5	26	100.00	100.00	100.00	100.00
Xa5	27	100.00	100.00	100.00	100.00
Za5	28	100.00	100.00	100.00	100.00
CM16	29	100.00	100.00	100.00	100.00
CM26	30	100.00	100.00	100.00	100.00
DK6	31	100.00	100.00	100.00	100.00
HM6	32	100.00	100.00	100.00	100.00
JM6	33	100.00	100.00	100.00	100.00
KB6	34	100.00	100.00	100.00	100.00
NB6	35	100.00	100.00	100.00	100.00
RS6	36	100.00	100.00	100.00	100.00
SB6	37	100.00	100.00	100.00	100.00
DQ7	38	100.00	100.00	100.00	100.00
DR7	39	100.00	100.00	100.00	100.00
EO7	40	100.00	100.00	100.00	100.00

Appendix 4.5 Individual clinical children: Single repetition accuracy total scores (binary) and mean scores (PCC), across the stimulus conditions, compared to the typical group mean scores.

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID	Total binary /24	Z score	Sig/not sig	Mean PCC	Z score	Sig/not sig
AJ4	16.00	-4.99	p<0.001	92.00	-2.82	p<0.01
DC4	5.00	-12.47	p<0.001	39.33	-24.15	p<0.001
EW4						
JJ4	16.00	-4.99	p<0.001	88.67	-4.17	p<0.001
LR4	19.00	-2.95	p<0.01	90.67	-3.36	p<0.001
MP4	16.00	-4.99	p<0.001	79.00	-8.09	p<0.001
PG4	3.00	-13.83	p<0.001	48.33	-20.50	p<0.001
SB4	8.00	-10.43	p<0.001	59.33	-16.05	p<0.001
TB4	22.00	-0.90	ns	96.00	-1.20	ns
TH4	6.00	-11.79	p<0.001	73.00	-10.51	p<0.001
ChS5	24.00	0.46	ns	100.00	0.42	ns
CS5	2.00	-14.51	p<0.001	49.33	-20.10	p<0.001
DG5	19.00	-2.95	p<0.001	95.00	-1.61	ns
EN5	23.00	-0.22	ns	98.67	-0.12	ns
IF5	21.00	-1.59	ns	96.00	-1.20	ns
IT5	13.00	-7.03	p<0.001	69.67	-11.86	p<0.001
JB5	16.00	-4.99	p<0.001	88.00	-4.44	p<0.001
JC5	23.00	-0.22	ns	100.00	0.42	ns
JK5	8.00	-10.43	p<0.001	71.33	-11.19	p<0.001
KK5	14.00	-6.35	p<0.001	73.00	-10.51	p<0.001
KW5	16.00	-4.99	p<0.001	86.33	-5.12	p<0.001
LS5	12.00	-7.71	p<0.001	72.00	-10.92	p<0.001
OB5	16.00	-4.99	p<0.001	86.67	-4.98	p<0.001
OP5	12.00	-7.71	p<0.001	73.67	-10.24	p<0.001
PBS5	23.00	-0.22	ns	98.67	-0.12	ns
RB5	19.00	-2.95	p<0.001	89.33	-3.90	p<0.001
RH5	3.00	-13.83	p<0.001	61.00	-15.37	p<0.001
RW5	24.00	0.46	ns	100.00	0.42	ns
SH5	23.00	-0.22	ns	98.00	-0.39	ns
TN5	22.00	-0.90	ns	100.00	0.42	ns
AG6	11.00	-8.39	p<0.001	74.67	-9.84	p<0.001
CC6	20.00	-2.27	p<0.05	94.00	-2.01	p<0.05
EC6	16.00	-4.99	p<0.001	81.00	-7.28	p<0.001
HL6	12.00	-7.71	p<0.001	77.67	-8.62	p<0.001
HM6	24.00	0.46	ns	100.00	0.42	ns
KH6	24.00	0.46	ns	100.00	0.42	ns
TC6	15.00	-5.67	p<0.001	87.67	-4.57	p<0.001
TM6	14.00	-6.35	p<0.001	86.00	-5.25	p<0.001
JC7	23.00	-0.22	ns	98.67	-0.12	ns
SC7	22.00	-0.90	ns	100.00	0.42	ns

Appendix 4.6 Clinical children: Five repetitions raw accuracy scores (binary) by stimulus condition (/8) and combined mean totals (/24).

Key: Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words /8	Non words /8	Syllable sequences /8	Combined mean total /24
AJ4	41	2.00	4.00	5.00	11.00
DC4	42	2.00	.00	1.00	3.00
EW4	43	.00	1.00		
JJ4	44	2.00	3.00	1.00	6.00
LR4	45	3.00	2.00	5.00	10.00
MP4	46	4.00	4.00	5.00	13.00
PG4	47	1.00	1.00	1.00	3.00
SB4	48	1.00	1.00	1.00	3.00
TB4	49	6.00	4.00	2.00	12.00
TH4	50	2.00	1.00	.00	3.00
ChS5	51	8.00	7.00	4.00	19.00
CS5	52	2.00	.00	.00	2.00
DG5	53	7.00	2.00	5.00	14.00
EN5	54	5.00	4.00	4.00	13.00
IF5	55	7.00	5.00	4.00	16.00
IT5	56	3.00	3.00	4.00	10.00
JB5	57	5.00	1.00	3.00	9.00
JC5	58	8.00	8.00	7.00	23.00
JK5	59	.00	.00	3.00	3.00
KK5	60	4.00	2.00	2.00	8.00
KW5	61	1.00	3.00	3.00	7.00
LS5	62	.00	3.00	2.00	5.00
OB5	63	3.00	4.00	4.00	11.00
OP5	64	1.00	2.00	2.00	5.00
PBS5	65	8.00	6.00	6.00	20.00
RB5	66	6.00	4.00	5.00	15.00
RH5	67	1.00	.00	.00	1.00
RW5	68	6.00	7.00	7.00	20.00
SH5	69	8.00	7.00	7.00	22.00
TN5	70	6.00	4.00	2.00	12.00
AG6	71	3.00	1.00	3.00	7.00
CC6	72	6.00	5.00	2.00	13.00
EC6	73	3.00	1.00	2.00	6.00
HL6	74	2.00	1.00	2.00	5.00
HM6	75	7.00	6.00	5.00	18.00
KH6	76	7.00	8.00	7.00	22.00
TC6	77	3.00	6.00	5.00	13.00
TM6	78	4.00	3.00	3.00	10.00
JC7	79	8.00	8.00	7.00	23.00
SC7	80	5.00	6.00	5.00	16.00

Appendix 4.7 Clinical children: Five repetitions raw accuracy scores (PCC) by stimulus condition and mean PCC across the conditions.

Key: PCC=percentage consonants correct; Child's ID=child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words	Non words	Syllable sequences	Mean PCC
AJ4	41	92.00	87.00	88.00	89.00
DC4	42	44.00	36.00	40.00	40.00
EW4	43	47.00	61.00		
JJ4	44	74.00	78.00	78.00	76.67
LR4	45	85.00	80.00	96.00	87.00
MP4	46	83.00	77.00	91.00	83.67
PG4	47	46.00	47.00	44.00	45.67
SB4	48	51.00	50.00	54.00	51.67
TB4	49	93.00	95.00	81.00	89.67
TH4	50	71.00	63.00	51.00	61.67
ChS5	51	100.00	100.00	92.00	97.33
CS5	52	54.00	32.00	30.00	38.67
DG5	53	95.00	83.00	100.00	92.67
EN5	54	96.00	93.00	88.00	92.33
IF5	55	100.00	95.00	85.00	93.33
IT5	56	68.00	63.00	72.00	67.67
JB5	57	88.00	78.00	87.00	84.33
JC5	58	100.00	100.00	96.00	98.67
JK5	59	62.00	63.00	70.00	65.00
KK5	60	70.00	73.00	64.00	69.00
KW5	61	69.00	77.00	83.00	76.33
LS5	62	44.00	78.00	61.00	61.00
OB5	63	83.00	96.00	76.00	85.00
OP5	64	55.00	64.00	67.00	62.00
PBS5	65	100.00	100.00	98.00	99.33
RB5	66	96.00	85.00	79.00	86.67
RH5	67	50.00	54.00	54.00	52.67
RW5	68	100.00	99.00	100.00	99.67
SH5	69	100.00	100.00	98.00	99.33
TN5	70	98.00	95.00	92.00	95.00
AG6	71	71.00	75.00	75.00	73.67
CC6	72	92.00	89.00	90.00	90.33
EC6	73	77.00	68.00	69.00	71.33
HL6	74	74.00	77.00	77.00	76.00
HM6	75	100.00	97.00	98.00	98.33
KH6	76	99.00	100.00	100.00	99.67
TC6	77	82.00	98.00	88.00	89.33
TM6	78	84.00	76.00	83.00	81.00
JC7	79	100.00	100.00	96.00	98.67
SC7	80	94.00	98.00	86.00	92.67

Appendix 4.8 Typical children: Five repetitions raw accuracy scores (binary) by stimulus condition (/8) and combined mean totals (/24).

Key: Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words /8	Non words /8	Syllable sequences /8	Combined mean total /24
AL4	1	6.00	5.00	6.00	17.00
An4	2	7.00	8.00	8.00	23.00
Ann4	3	8.00	8.00	7.00	23.00
Bel4	4	5.00	7.00	7.00	19.00
BN4	5	7.00	5.00	5.00	17.00
Is4	6	7.00	3.00	6.00	16.00
Ja4	7	7.00	5.00	7.00	19.00
Jo4	8	8.00	7.00	7.00	22.00
Ma4	9	5.00	6.00	6.00	17.00
Ni4	10	7.00	2.00	5.00	14.00
Re4	11	5.00	8.00	6.00	19.00
AB5	12	4.00	5.00	5.00	14.00
AL5	13	7.00	4.00	6.00	17.00
Anl5	14	8.00	8.00	7.00	23.00
Ao5	15	7.00	6.00	6.00	19.00
CE5	16	8.00	6.00	7.00	21.00
Da5	17	6.00	5.00	6.00	17.00
EL5	18	8.00	7.00	5.00	20.00
Ha5	19	4.00	5.00	4.00	13.00
Is5	20	7.00	7.00	7.00	21.00
Lo5	21	6.00	6.00	6.00	18.00
Ra5	22	5.00	8.00	5.00	18.00
Rh5	23	8.00			
Ro5	24	6.00	4.00	5.00	15.00
SO5	25	8.00	7.00	7.00	22.00
Ta5	26	8.00	8.00	7.00	23.00
Xa5	27	8.00	6.00	6.00	20.00
Za5	28	7.00	2.00	6.00	15.00
CM16	29	8.00	7.00	5.00	20.00
CM26	30	8.00	5.00	5.00	18.00
DK6	31	8.00	7.00	7.00	22.00
HM6	32	7.00	6.00	7.00	20.00
JM6	33	6.00	6.00	7.00	19.00
KB6	34	8.00	8.00	6.00	22.00
NB6	35	8.00	6.00	8.00	22.00
RS6	36	7.00	8.00	7.00	22.00
SB6	37	8.00	6.00	5.00	19.00
DQ7	38	7.00	7.00	7.00	21.00
DR7	39	6.00	7.00	5.00	18.00
EO7	40	5.00	8.00	8.00	21.00

Appendix 4.9 Typical children: Five repetitions raw accuracy scores (PCC) by stimulus condition and mean PCC across the conditions.

Key: PCC=percentage consonants correct; Child's ID=child's identification code; Child's no. =child's identification number.

Child's ID	Child's No.	Real words	Non words	Syllable sequences	Mean PCC
AL4	1	100.00	99.00	100.00	99.67
An4	2	100.00	100.00	100.00	100.00
Ann4	3	100.00	100.00	99.00	99.67
Bel4	4	99.00	100.00	100.00	99.67
BN4	5	98.00	99.00	100.00	99.00
Is4	6	98.00	81.00	99.00	92.67
Ja4	7	100.00	98.00	97.00	98.33
Jo4	8	100.00	100.00	100.00	100.00
Ma4	9	99.00	98.00	94.00	97.00
Ni4	10	100.00	99.00	90.00	96.33
Re4	11	97.00	100.00	95.00	97.33
AB5	12	90.00	87.00	92.00	89.67
AL5	13	99.00	84.00	98.00	93.67
Anl5	14	100.00	100.00	99.00	99.67
Ao5	15	96.00	100.00	88.00	94.67
CE5	16	100.00	96.00	100.00	98.67
Da5	17	99.00	96.00	97.00	97.33
EL5	18	100.00	100.00	98.00	99.33
Ha5	19	96.00	86.00	84.00	88.67
Is5	20	100.00	100.00	99.00	99.67
Lo5	21	96.00	97.00	95.00	96.00
Ra5	22	100.00	100.00	96.00	98.67
Rh5	23	100.00			
Ro5	24	98.00	89.00	90.00	92.33
SO5	25	100.00	99.00	98.00	99.00
Ta5	26	100.00	100.00	100.00	100.00
Xa5	27	100.00	100.00	95.00	98.33
Za5	28	100.00	81.00	100.00	93.67
CM16	29	100.00	98.00	98.00	98.67
CM26	30	99.00	100.00	99.00	99.33
DK6	31	100.00	98.00	100.00	99.33
HM6	32	99.00	96.00	100.00	98.33
JM6	33	96.00	99.00	99.00	98.00
KB6	34	100.00	100.00	91.00	97.00
NB6	35	100.00	99.00	100.00	99.67
RS6	36	99.00	100.00	100.00	99.67
SB6	37	100.00	99.00	96.00	98.33
DQ7	38	100.00	99.00	100.00	99.67
DR7	39	99.00	99.00	98.00	98.67
EO7	40	88.00	100.00	100.00	96.00

Appendix 4.10 Individual Clinical children: Five repetitions accuracy total scores (binary) and mean scores (PCC), across the stimulus conditions, compared to the typical group mean scores.

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID.	Child's No.	Total binary /24	Z score	Sig./not sig.	Mean PCC	Z score	Sig./not sig.
AJ4	41	11.00	-2.96	p<0.01	89.00	-3.08	p<0.01
DC4	42	3.00	-5.87	p<0.001	40.00	-20.03	p<0.001
EW4	43						
JJ4	44	6.00	-4.77	p<0.001	76.67	-7.57	p<0.001
LR4	45	10.00	-3.32	p<0.001	87.00	-3.65	p<0.001
MP4	46	13.00	-2.23	p<0.05	83.67	-5.02	p<0.001
PG4	47	3.00	-5.87	p<0.001	45.67	-18.05	p<0.001
SB4	48	3.00	-5.87	p<0.001	51.67	-16.66	p<0.001
TB4	49	12.00	-2.59	p<0.01	89.67	-2.72	p<0.01
TH4	50	3.00	-5.87	p<0.001	61.67	-13.02	p<0.001
ChS5	51	19.00	-0.05	ns	97.33	-0.05	ns
CS5	52	2.00	-6.23	p<0.001	38.67	-21.39	p<0.001
DG5	53	14.00	-1.87	p<0.05	92.67	-1.75	p<0.05
EN5	54	13.00	-2.23	p<0.05	92.33	-1.87	p<0.05
IF5	55	16.00	-1.14	ns	93.33	-1.51	ns
IT5	56	10.00	-3.32	p<0.001	67.67	-10.39	p<0.001
JB5	57	9.00	-3.68	p<0.001	84.33	-4.78	p<0.001
JC5	58	23.00	1.41	ns	98.67	0.43	ns
JK5	59	3.00	-5.87	p<0.001	65.00	-11.81	p<0.001
KK5	60	8.00	-4.05	p<0.001	69.00	-10.36	p<0.001
KW5	61	7.00	-4.41	p<0.001	76.33	-7.69	p<0.001
LS5	62	5.00	-5.14	p<0.001	61.00	-13.27	p<0.001
OB5	63	11.00	-2.96	p<0.01	85.00	-4.54	p<0.001
OP5	64	5.00	-5.14	p<0.001	62.00	-12.90	p<0.001
PBS5	65	20.00	0.32	ns	99.33	0.67	ns
RB5	66	15.00	-1.50	ns	86.67	-3.93	p<0.001
RH5	67	1.00	-6.59	p<0.001	52.67	-16.29	p<0.001
RW5	68	20.00	0.32	ns	99.67	0.80	ns
SH5	69	22.00	1.04	ns	99.33	0.67	ns
TN5	70	12.00	-2.59	p<0.01	95.00	-0.90	ns
AG6	71	7.00	-4.41	p<0.001	73.67	-8.66	p<0.001
CC6	72	13.00	-2.23	p<0.05	90.33	-2.60	p<0.01
EC6	73	6.00	-4.77	p<0.001	71.33	-9.51	p<0.001
HL6	74	5.00	-5.14	p<0.001	76.00	-7.81	p<0.001
HM6	75	18.00	-0.41	ns	98.33	0.31	ns
KH6	76	22.00	1.04	ns	99.67	0.80	ns
TC6	77	13.00	-2.23	p<0.05	89.33	-2.96	p<0.01
TM6	78	10.00	-3.32	p<0.001	81.00	-5.99	p<0.001
JC7	79	23.00	1.41	ns	98.67	0.43	ns
SC7	80	16.00	-1.14	ns	92.67	-1.75	p<0.05

Appendix 4.11 Clinical children: Single repetition accuracy raw scores (binary) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences.

Child's ID	RW 2 /4	RW3 /4	NW2 /4	NW3 /4	SS2 /4	SS3 /4	Mean 2 /4	Mean 3 /4
AJ4	3.00	2.00	3.00	2.00	4.00	2.00	3.33	2.00
DC4	2.00	1.00	1.00	.00	1.00	.00	1.33	.33
EW4	.00	.00	2.00	.00				
JJ4	4.00	3.00	4.00	1.00	3.00	1.00	3.67	1.67
LR4	3.00	3.00	2.00	3.00	4.00	4.00	3.00	3.33
MP4	3.00	1.00	3.00	3.00	4.00	2.00	3.33	2.00
PG4	1.00	.00	1.00	.00	1.00	.00	1.00	.00
SB4	1.00	.00	2.00	.00	1.00	2.00	1.33	.67
TB4	4.00	4.00	4.00	3.00	4.00	3.00	4.00	3.33
TH4	2.00	.00	2.00	.00	2.00	.00	2.00	.00
ChS5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
CS5	2.00	.00	.00	.00	.00	.00	.67	.00
DG5	4.00	3.00	4.00	2.00	4.00	2.00	4.00	2.33
EN5	4.00	3.00	4.00	4.00	4.00	4.00	4.00	3.67
IF5	4.00	4.00	4.00	3.00	4.00	2.00	4.00	3.00
IT5	3.00	1.00	3.00	1.00	3.00	2.00	3.00	1.33
JB5	4.00	1.00	4.00	1.00	4.00	2.00	4.00	1.33
JC5	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.67
JK5	.00	2.00	1.00	1.00	3.00	1.00	1.33	1.33
KK5	4.00	2.00	4.00	.00	3.00	1.00	3.67	1.00
KW5	2.00	2.00	3.00	3.00	3.00	3.00	2.67	2.67
LS5	1.00	.00	3.00	2.00	3.00	3.00	2.33	1.67
OB5	3.00	1.00	3.00	4.00	4.00	1.00	3.33	2.00
OP5	1.00	3.00	2.00	2.00	2.00	2.00	1.67	2.33
PBS5	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.67
RB5	4.00	2.00	3.00	3.00	4.00	3.00	3.67	2.67
RH5	1.00	.00	1.00	.00	1.00	.00	1.00	.00
RW5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
SH5	4.00	4.00	3.00	4.00	4.00	4.00	3.67	4.00
TN5	4.00	4.00	4.00	4.00	4.00	2.00	4.00	3.33
AG6	4.00	.00	2.00	2.00	2.00	1.00	2.67	1.00
CC6	4.00	3.00	3.00	3.00	4.00	3.00	3.67	3.00
EC6	2.00	2.00	4.00	2.00	3.00	3.00	3.00	2.33
HL6	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
HM6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
KH6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
TC6	3.00	1.00	3.00	3.00	4.00	1.00	3.33	1.67
TM6	4.00	1.00	4.00	1.00	3.00	1.00	3.67	1.00
JC7	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
SC7	4.00	3.00	4.00	4.00	4.00	3.00	4.00	3.33

Appendix 4.12 Clinical children: Single repetition accuracy raw scores (PCC) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: PCC= percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AJ4	100.00	83.00	100.00	83.00	100.00	83.00	100.00	83.00
DC4	63.00	25.00	50.00	25.00	50.00	22.00	54.33	24.00
EW4	38.00	50.00	75.00	78.00				
JJ4	100.00	92.00	100.00	75.00	88.00	75.00	96.00	80.67
LR4	88.00	100.00	63.00	92.00	100.00	100.00	83.67	97.33
MP4	88.00	50.00	75.00	92.00	100.00	67.00	87.67	69.67
PG4	50.00	42.00	50.00	42.00	63.00	42.00	54.33	42.00
SB4	50.00	58.00	63.00	50.00	50.00	83.00	54.33	63.67
TB4	100.00	100.00	100.00	92.00	100.00	83.00	100.00	91.67
TH4	75.00	67.00	88.00	67.00	75.00	64.00	79.33	66.00
ChS5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CS5	75.00	71.00	38.00	44.00	38.00	30.00	50.33	48.33
DG5	100.00	92.00	100.00	92.00	100.00	92.00	100.00	92.00
EN5	100.00	92.00	100.00	100.00	100.00	100.00	100.00	97.33
IF5	100.00	100.00	100.00	92.00	100.00	83.00	100.00	91.67
IT5	75.00	67.00	75.00	58.00	75.00	67.00	75.00	64.00
JB5	100.00	75.00	100.00	67.00	100.00	83.00	100.00	75.00
JC5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
JK5	50.00	83.00	63.00	75.00	88.00	67.00	67.00	75.00
KK5	100.00	42.00	100.00	50.00	88.00	58.00	96.00	50.00
KW5	75.00	83.00	88.00	92.00	88.00	92.00	83.67	89.00
LS5	38.00	50.00	88.00	83.00	88.00	83.00	71.33	72.00
OB5	88.00	67.00	88.00	100.00	100.00	75.00	92.00	80.67
OP5	63.00	75.00	63.00	83.00	75.00	83.00	67.00	80.33
PBS5	100.00	100.00	100.00	92.00	100.00	100.00	100.00	97.33
RB5	100.00	91.00	75.00	92.00	100.00	75.00	91.67	86.00
RH5	63.00	50.00	63.00	58.00	63.00	67.00	63.00	58.33
RW5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
SH5	100.00	100.00	88.00	100.00	100.00	100.00	96.00	100.00
TN5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
AG6	88.00	67.00	75.00	75.00	75.00	67.00	79.33	69.67
CC6	100.00	92.00	88.00	92.00	100.00	92.00	96.00	92.00
EC6	63.00	83.00	100.00	67.00	88.00	83.00	83.67	77.67
HL6	75.00	75.00	75.00	83.00	75.00	83.00	75.00	80.33
HM6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
KH6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TC6	88.00	73.00	88.00	100.00	100.00	75.00	92.00	82.67
TM6	100.00	75.00	100.00	75.00	88.00	75.00	96.00	75.00
JC7	100.00	100.00	100.00	100.00	100.00	92.00	100.00	97.33
SC7	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix 4.13 Typical children: Single repetition accuracy raw scores (binary) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS£=3 syllable, syllable sequences.

Child's ID	RW 2 /4	RW3 /4	NW2 /4	NW3 /4	SS2 /4	SS3 /4	Mean 2 /4	Mean 3 /4
AL4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
An4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ann4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Bel4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
BN4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Is4	4.00	4.00	2.00	4.00	4.00	4.00	3.33	4.00
Ja4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Jo4	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.67
Ma4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ni4	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.67
Re4	4.00	3.00	4.00	4.00	4.00	3.00	4.00	3.33
AB5	4.00	2.00	4.00	2.00	3.00	2.00	3.67	2.00
AL5	4.00	2.00	4.00	4.00	4.00	4.00	4.00	3.33
Anl5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ao5	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.67
CE5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Da5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
EL5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ha5	4.00	3.00	4.00	3.00	4.00	2.00	4.00	2.67
Is5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Lo5	4.00	4.00	4.00	4.00	3.00	3.00	3.67	3.67
Ra5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Rh5	4.00	4.00						
Ro5	4.00	2.00	4.00	3.00	4.00	3.00	4.00	2.67
SO5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Ta5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Xa5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Za5	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
CM16	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
CM26	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DK6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
HM6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
JM6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
KB6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NB6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
RS6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
SB6	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DQ7	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DR7	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
EO7	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Appendix 4.14 Typical children: Single repetition accuracy raw scores (PCC) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: PCC= percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AL4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
An4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ann4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bel4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
BN4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Is4	100.00	100.00	75.00	92.00	100.00	100.00	91.67	97.33
Ja4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jo4	100.00	100.00	100.00	92.00	100.00	100.00	100.00	97.33
Ma4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ni4	100.00	100.00	100.00	92.00	100.00	100.00	100.00	97.33
Re4	100.00	92.00	100.00	100.00	100.00	92.00	100.00	94.67
AB5	100.00	83.00	100.00	83.00	88.00	67.00	96.00	77.67
AL5	100.00	83.00	100.00	100.00	100.00	100.00	100.00	94.33
Anl5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ao5	100.00	100.00	100.00	92.00	100.00	100.00	100.00	97.33
CE5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Da5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
EL5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ha5	100.00	92.00	100.00	83.00	100.00	83.00	100.00	86.00
Is5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Lo5	100.00	100.00	100.00	100.00	88.00	92.00	96.00	97.33
Ra5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rh5	100.00	100.00						
Ro5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
SO5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ta5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Xa5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Za5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CM16	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CM26	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
DK6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
HM6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
JM6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
KB6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
NB6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
RS6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
SB6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
DQ7	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
DR7	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
EO7	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix 4.15 Individual clinical children: Single repetition accuracy mean scores (binary) by stimulus length, across the stimulus conditions, compared to typical group mean scores.
Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID	Mean 2 syll /4	Z score	Sig/not sig	Mean 3 syll /4	Z score	Sig/not sig
AJ4	3.33	-4.92	p<0.001	2.00	-4.14	p<0.001
DC4	1.33	-20.30	p<0.001	.33	-7.93	p<0.001
EW4	1.00	-22.85	p<0.001	.00	-8.68	p<0.001
JJ4	3.67	-2.31	p<0.05	1.67	-4.89	p<0.001
LR4	3.00	-7.46	p<0.001	3.33	-1.11	ns
MP4	3.33	-4.92	p<0.001	2.00	-4.14	p<0.001
PG4	1.00	-22.85	p<0.001	.00	-8.68	p<0.001
SB4	1.33	-20.31	p<0.001	.67	-7.16	p<0.001
TB4	4.00	0.23	ns	3.33	-1.11	ns
TH4	2.00	-15.15	p<0.001	.00	-8.68	p<0.001
ChS5	4.00	0.23	ns	4.00	0.41	ns
CS5	.67	25.38	p<0.001	.00	-8.68	p<0.001
DG5	4.00	0.23	ns	2.33	-3.39	p<0.001
EN5	4.00	0.23	ns	3.67	-0.34	ns
IF5	4.00	0.23	ns	3.00	-1.86	p<0.05
IT5	3.00	-7.46	p<0.001	1.33	-5.66	p<0.001
JB5	4.00	0.23	ns	1.33	-5.66	p<0.001
JC5	4.00	0.23	ns	3.67	-0.34	ns
JK5	1.33	-20.30	p<0.001	1.33	-5.66	p<0.001
KK5	3.67	-2.31	p<0.05	1.00	-6.41	p<0.001
KW5	2.67	-10.00	p<0.001	2.67	-2.61	p<0.01
LS5	2.33	-12.62	p<0.001	1.67	-4.89	p<0.001
OB5	3.33	-4.92	p<0.001	2.00	-4.14	p<0.001
OP5	1.67	-17.70	p<0.001	2.33	-3.39	p<0.001
PBS5	4.00	0.23	ns	3.67	-0.34	ns
RB5	3.67	-2.31	p<0.05	2.67	-2.61	p<0.01
RH5	1.00	-22.85	p<0.001	.00	-8.68	p<0.001
RW5	4.00	0.23	ns	4.00	0.41	ns
SH5	3.67	-2.31	p<0.05	4.00	0.41	ns
TN5	4.00	0.23	ns	3.33	-1.11	ns
AG6	2.67	-10.00	p<0.001	1.00	-6.41	p<0.001
CC6	3.67	-2.31	p<0.05	3.00	-1.86	p<0.05
EC6	3.00	-7.46	p<0.001	2.33	-3.39	p<0.001
HL6	2.00	-15.15	p<0.001	2.00	-4.14	p<0.001
HM6	4.00	0.23	ns	4.00	0.41	ns
KH6	4.00	0.23	ns	4.00	0.41	ns
TC6	3.33	-4.92	p<0.001	1.67	-4.89	p<0.001
TM6	3.67	-2.31	p<0.05	1.00	-6.41	p<0.001
JC7	4.00	0.23	ns	3.67	-0.34	ns
SC7	4.00	0.23	ns	3.33	-1.11	ns

Appendix 4.16 Individual clinical children (n=40): Single repetition accuracy mean scores (PCC) by stimulus length, across the stimulus conditions, compared to typical group mean scores.

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level

Child's ID	Mean 2	Z score	Sig/not sig	Mean 3	Z score	Sig/not sig
AJ4	100.00	0.27	ns	83.00	-3.61	p<0.001
DC4	54.33	-28.64	p<0.001	24.00	-17.39	p<0.001
EW4						
JJ4	96.00	-2.27	p<0.05	80.67	-4.15	p<0.001
LR4	83.67	-10.07	p<0.001	97.33	-0.26	ns
MP4	87.67	-7.54	p<0.001	69.67	-6.72	p<0.001
PG4	54.33	-28.64	p<0.001	42.00	-13.19	p<0.001
SB4	54.33	-28.64	p<0.001	63.67	-8.12	p<0.001
TB4	100.00	0.27	ns	91.67	-1.58	ns
TH4	79.33	-12.82	p<0.001	66.00	-7.58	p<0.001
ChS5	100.00	0.27	ns	100.00	0.36	ns
CS5	50.33	-31.17	p<0.001	48.33	-11.71	p<0.001
DG5	100.00	0.27	ns	92.00	-1.50	ns
EN5	100.00	0.27	ns	97.33	-0.26	ns
IF5	100.00	0.27	ns	91.67	-1.58	ns
IT5	75.00	-15.56	p<0.001	64.00	-8.05	p<0.001
JB5	100.00	0.27	ns	75.00	-5.48	p<0.001
JC5	100.00	0.27	ns	100.00	0.36	ns
JK5	67.00	-20.62	p<0.001	75.00	-5.48	p<0.001
KK5	96.00	-2.27	p<0.05	50.00	-11.32	p<0.001
KW5	83.67	-10.07	p<0.001	89.00	-2.21	p<0.05
LS5	71.33	-17.88	p<0.001	72.00	-6.18	p<0.001
OB5	92.00	-4.80	p<0.001	80.67	-4.15	p<0.001
OP5	67.00	-20.62	p<0.001	80.33	-4.23	p<0.001
PBS5	100.00	0.27	ns	97.33	-0.26	ns
RB5	91.67	-5.01	p<0.001	86.00	-2.91	p<0.01
RH5	63.00	-23.15	p<0.001	58.33	-9.37	p<0.001
RW5	100.00	0.27	ns	100.00	0.36	ns
SH5	96.00	-2.27	p<0.05	100.00	0.36	ns
TN5	100.00	0.27	ns	100.00	0.36	ns
AG6	79.33	-12.81	p<0.001	69.67	-6.72	p<0.001
CC6	96.00	-2.27	p<0.05	92.00	-1.50	ns
EC6	83.67	-10.07	p<0.001	77.67	-4.85	p<0.001
HL6	75.00	-15.56	p<0.001	80.33	-4.23	p<0.001
HM6	100.00	0.27	ns	100.00	0.36	ns
KH6	100.00	0.27	ns	100.00	0.36	ns
TC6	92.00	-4.80	p<0.001	82.67	-3.68	p<0.001
TM6	96.00	-2.27	p<0.05	75.00	-5.48	p<0.001
JC7	100.00	0.27	ns	97.33	-0.26	ns
SC7	100.00	0.27	ns	100.00	0.36	ns

Appendix 4.17 Clinical children: Five repetitions accuracy raw scores (binary) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean of RW, NW & SS; Mean 3=mean of RW, NW & SS.

Child's ID	RW 2 /4	RW3 /4	NW2 /4	NW3 /4	SS2 /4	SS3 /4	Mean 2 /4	Mean 3 /4
AJ4	2.00	.00	3.00	1.00	4.00	1.00	3.00	.67
DC4	2.00	.00	.00	.00	1.00	.00	1.00	.00
EW4	.00	.00	1.00	.00				
JJ4	2.00	.00	3.00	.00	.00	1.00	1.67	.33
LR4	2.00	1.00	1.00	1.00	4.00	1.00	2.33	1.00
MP4	3.00	1.00	3.00	1.00	3.00	2.00	3.00	1.33
PG4	1.00	.00	1.00	.00	1.00	.00	1.00	.00
SB4	1.00	.00	1.00	.00	1.00	.00	1.00	.00
TB4	4.00	2.00	1.00	3.00	2.00	.00	2.33	1.67
TH4	2.00	.00	1.00	.00	.00	.00	1.00	.00
ChS5	4.00	4.00	3.00	4.00	3.00	1.00	3.33	3.00
CS5	2.00	.00	.00	.00	.00	.00	.67	.00
DG5	4.00	3.00	2.00	.00	4.00	1.00	3.33	1.33
EN5	3.00	2.00	3.00	1.00	2.00	2.00	2.67	1.67
IF5	4.00	3.00	3.00	2.00	3.00	1.00	3.33	2.00
IT5	2.00	1.00	3.00	.00	3.00	1.00	2.67	.67
JB5	4.00	1.00	1.00	.00	2.00	1.00	2.33	.67
JC5	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
JK5	.00	.00	.00	1.00	2.00	1.00	.67	.67
KK5	3.00	1.00	1.00	1.00	2.00	.00	2.00	.67
KW5	1.00	.00	2.00	1.00	2.00	1.00	1.67	.67
LS5	.00	.00	2.00	1.00	1.00	1.00	1.00	.67
OB5	3.00	.00	3.00	1.00	3.00	1.00	3.00	.67
OP5	1.00	.00	2.00	.00	2.00	.00	1.67	.00
PBS5	4.00	4.00	4.00	2.00	4.00	2.00	4.00	2.67
RB5	4.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00
RH5	1.00	.00	.00	.00	.00	.00	.33	.00
RW5	4.00	2.00	4.00	3.00	4.00	3.00	4.00	2.67
SH5	4.00	4.00	3.00	4.00	4.00	3.00	3.67	3.67
TN5	4.00	2.00	3.00	1.00	2.00	.00	3.00	1.00
AG6	2.00	1.00	1.00	.00	2.00	1.00	1.67	.67
CC6	4.00	2.00	2.00	3.00	2.00	.00	2.67	1.67
EC6	2.00	1.00	1.00	.00	1.00	1.00	1.33	.67
HL6	2.00	.00	1.00	.00	1.00	1.00	1.33	.33
HM6	4.00	3.00	2.00	4.00	4.00	1.00	3.33	2.67
KH6	4.00	3.00	4.00	4.00	4.00	3.00	4.00	3.33
TC6	2.00	1.00	4.00	2.00	4.00	1.00	3.33	1.33
TM6	4.00	.00	3.00	.00	3.00	.00	3.33	.00
JC7	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
SC7	3.00	2.00	3.00	3.00	3.00	2.00	3.00	2.33

Appendix 4.18 Clinical children: Five repetitions accuracy raw scores (PCC) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: PCC= percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AJ4	95.00	88.00	100.00	74.00	100.00	75.00	98.33	79.00
DC4	63.00	25.00	47.00	25.00	56.00	24.00	55.33	24.67
EW4	38.00	55.00	66.00	56.00				
JJ4	82.00	65.00	88.00	67.00	85.00	70.00	85.00	67.33
LR4	88.00	81.00	75.00	85.00	100.00	92.00	87.67	86.00
MP4	88.00	77.00	75.00	78.00	98.00	84.00	87.00	79.67
PG4	50.00	41.00	50.00	44.00	45.00	43.00	48.33	42.67
SB4	43.00	58.00	50.00	49.00	50.00	58.00	47.67	55.00
TB4	98.00	88.00	89.00	100.00	87.00	74.00	91.33	87.33
TH4	75.00	67.00	58.00	67.00	50.00	52.00	61.00	62.00
ChS5	100.00	100.00	100.00	100.00	95.00	89.00	98.33	96.33
CS5	63.00	45.00	16.00	47.00	44.00	16.00	41.00	36.00
DG5	100.00	92.00	75.00	90.00	100.00	100.00	91.67	94.00
EN5	100.00	91.00	93.00	93.00	88.00	88.00	93.67	90.67
IF5	100.00	100.00	97.00	92.00	88.00	81.00	95.00	91.00
IT5	68.00	67.00	75.00	51.00	79.00	65.00	74.00	61.00
JB5	100.00	75.00	95.00	60.00	97.00	77.00	97.33	70.67
JC5	100.00	100.00	100.00	100.00	100.00	92.00	100.00	97.33
JK5	50.00	73.00	50.00	75.00	75.00	65.00	58.33	71.00
KK5	88.00	52.00	65.00	81.00	97.00	30.00	83.33	54.33
KW5	63.00	75.00	80.00	73.00	80.00	86.00	74.33	78.00
LS5	34.00	54.00	80.00	75.00	58.00	63.00	57.33	64.00
OB5	88.00	78.00	92.00	100.00	88.00	63.00	89.33	80.33
OP5	53.00	56.00	63.00	65.00	68.00	65.00	61.33	62.00
PBS5	100.00	100.00	100.00	100.00	100.00	96.00	100.00	98.67
RB5	100.00	91.00	75.00	95.00	88.00	70.00	87.67	85.33
RH5	50.00	50.00	50.00	58.00	55.00	53.00	51.67	53.67
RW5	100.00	100.00	100.00	98.00	100.00	100.00	100.00	99.33
SH5	100.00	100.00	100.00	100.00	100.00	96.00	100.00	98.67
TN5	100.00	96.00	100.00	90.00	100.00	83.00	100.00	89.67
AG6	75.00	67.00	75.00	75.00	78.00	72.00	76.00	71.33
CC6	100.00	84.00	85.00	92.00	92.00	88.00	92.33	88.00
EC6	63.00	91.00	73.00	62.00	75.00	62.00	70.33	71.67
HL6	75.00	72.00	76.00	76.00	75.00	78.00	75.33	75.33
HM6	100.00	100.00	94.00	100.00	100.00	96.00	98.00	98.67
KH6	100.00	98.00	100.00	100.00	100.00	100.00	100.00	99.33
TC6	87.00	76.00	100.00	96.00	100.00	75.00	95.67	82.33
TM6	100.00	68.00	87.00	65.00	98.00	67.00	95.00	66.67
JC7	100.00	100.00	100.00	100.00	100.00	92.00	100.00	97.33
SC7	100.00	88.00	100.00	95.00	88.00	83.00	96.00	88.67

Appendix 4.19 Typical children: Five repetitions accuracy raw scores (binary) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.
Key: Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean of RW, NW & SS; Mean 3=mean of RW, NW & SS.

Child's ID	RW 2 /4	RW3 /4	NW2 /4	NW3 /4	SS2 /4	SS3 /4	Mean 2 /4	Mean 3 /4
AL4	4.00	2.00	3.00	2.00	4.00	2.00	3.67	2.00
An4	4.00	3.00	4.00	4.00	4.00	4.00	4.00	3.67
Ann4	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
Bel4	2.00	3.00	3.00	4.00	4.00	3.00	3.00	3.33
BN4	4.00	3.00	3.00	2.00	4.00	1.00	3.67	2.00
Is4	4.00	3.00	2.00	1.00	4.00	2.00	3.33	2.00
Ja4	4.00	3.00	3.00	2.00	4.00	3.00	3.67	2.67
Jo4	4.00	4.00	4.00	3.00	4.00	3.00	4.00	3.33
Ma4	2.00	3.00	4.00	2.00	2.00	4.00	2.67	3.00
Ni4	4.00	3.00	1.00	1.00	4.00	1.00	3.00	1.67
Re4	3.00	2.00	4.00	4.00	4.00	2.00	3.67	2.67
AB5	3.00	1.00	4.00	1.00	3.00	2.00	3.33	1.33
AL5	4.00	3.00	3.00	1.00	4.00	2.00	3.67	2.00
Anl5	4.00	4.00	4.00	4.00	3.00	4.00	3.67	4.00
Ao5	4.00	3.00	4.00	2.00	3.00	3.00	3.67	2.67
CE5	4.00	4.00	4.00	2.00	3.00	4.00	3.67	3.33
Da5	4.00	2.00	3.00	2.00	4.00	2.00	3.67	2.00
EL5	4.00	4.00	4.00	3.00	3.00	2.00	3.67	3.00
Ha5	3.00	1.00	2.00	3.00	4.00	.00	3.00	1.33
Is5	4.00	3.00	3.00	4.00	4.00	3.00	3.67	3.33
Lo5	3.00	3.00	4.00	2.00	4.00	2.00	3.67	2.33
Ra5	4.00	1.00	4.00	4.00	4.00	1.00	4.00	2.00
Rh5	4.00	3.00						
Ro5	4.00	2.00	3.00	1.00	3.00	2.00	3.33	1.67
SO5	4.00	4.00	4.00	3.00	4.00	3.00	4.00	3.33
Ta5	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
Xa5	4.00	4.00	3.00	3.00	3.00	3.00	3.33	3.33
Za5	3.00	4.00	.00	2.00	4.00	2.00	2.33	2.67
CM16	4.00	4.00	3.00	4.00	3.00	2.00	3.33	3.33
CM26	4.00	3.00	3.00	2.00	3.00	2.00	3.33	2.33
DK6	4.00	4.00	3.00	4.00	3.00	4.00	3.33	4.00
HM6	4.00	3.00	3.00	3.00	4.00	3.00	3.67	3.00
JM6	4.00	2.00	3.00	3.00	4.00	3.00	3.67	2.67
KB6	4.00	4.00	4.00	4.00	4.00	2.00	4.00	3.33
NB6	4.00	4.00	4.00	2.00	4.00	4.00	4.00	3.33
RS6	4.00	3.00	4.00	4.00	4.00	3.00	4.00	3.33
SB6	4.00	4.00	2.00	4.00	3.00	2.00	3.00	3.33
DQ7	4.00	3.00	4.00	3.00	4.00	3.00	4.00	3.00
DR7	2.00	4.00	4.00	3.00	3.00	2.00	3.00	3.00
EO7	3.00	2.00	4.00	4.00	4.00	4.00	3.67	3.33

Appendix 4.20 Typical children: Five repetitions accuracy raw scores (PCC) by stimulus length (2 vs. 3 syllables) across the stimulus conditions and total mean scores.

Key: PCC= percentage consonants correct; Child's ID =child's identification code; Child's no. =child's identification number; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AL4	100.00	100.00	100.00	98.00	100.00	100.00	100.00	99.33
An4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ann4	100.00	100.00	100.00	100.00	100.00	98.00	100.00	99.33
Bel4	100.00	97.00	100.00	100.00	100.00	100.00	100.00	99.00
BN4	100.00	95.00	100.00	98.00	100.00	100.00	100.00	97.67
Is4	100.00	95.00	75.00	87.00	100.00	98.00	91.67	93.33
Ja4	100.00	100.00	97.00	98.00	100.00	93.00	99.00	97.00
Jo4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ma4	100.00	97.00	100.00	96.00	87.00	100.00	95.67	97.67
Ni4	100.00	100.00	97.00	100.00	100.00	79.00	99.00	93.00
Re4	97.00	96.00	100.00	100.00	100.00	90.00	99.00	95.33
AB5	100.00	79.00	100.00	74.00	100.00	84.00	100.00	79.00
AL5	100.00	98.00	88.00	80.00	100.00	95.00	96.00	91.00
Anl5	100.00	100.00	100.00	100.00	98.00	100.00	99.33	100.00
Ao5	100.00	92.00	100.00	100.00	97.00	78.00	99.00	90.00
CE5	100.00	100.00	100.00	91.00	100.00	100.00	100.00	97.00
Da5	100.00	98.00	98.00	93.00	100.00	94.00	99.33	95.00
EL5	100.00	100.00	100.00	100.00	100.00	96.00	100.00	98.67
Ha5	100.00	91.00	85.00	87.00	100.00	68.00	95.00	82.00
Is5	100.00	100.00	100.00	100.00	100.00	98.00	100.00	99.33
Lo5	100.00	92.00	100.00	93.00	100.00	89.00	100.00	91.33
Ra5	100.00	100.00	100.00	100.00	100.00	92.00	100.00	97.33
Rh5	100.00	100.00					100.00 *	100.00 *
Ro5	100.00	96.00	98.00	80.00	83.00	97.00	93.67	91.00
SO5	100.00	100.00	100.00	97.00	100.00	96.00	100.00	97.67
Ta5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Xa5	100.00	100.00	100.00	100.00	93.00	97.00	97.67	99.00
Za5	100.00	100.00	65.00	96.00	100.00	100.00	88.33	98.67
CM16	100.00	100.00	95.00	100.00	97.00	98.00	97.33	99.33
CM26	100.00	98.00	100.00	100.00	100.00	98.00	100.00	98.67
DK6	100.00	100.00	95.00	100.00	100.00	100.00	98.33	100.00
HM6	100.00	97.00	93.00	98.00	100.00	100.00	97.67	98.33
JM6	100.00	92.00	100.00	97.00	100.00	98.00	100.00	95.67
KB6	100.00	100.00	100.00	100.00	100.00	82.00	100.00	94.00
NB6	100.00	100.00	100.00	98.00	100.00	100.00	100.00	99.33
RS6	100.00	98.00	100.00	100.00	100.00	100.00	100.00	99.33
SB6	100.00	100.00	97.00	100.00	98.00	93.00	98.33	97.67
DQ7	100.00	100.00	100.00	97.00	100.00	100.00	100.00	99.00
DR7	97.00	100.00	100.00	98.00	100.00	96.00	99.00	98.00
EO7	88.00	88.00	100.00	100.00	100.00	100.00	96.00	96.00

Appendix 4.21 Individual clinical children (n=40): Five repetitions accuracy mean scores (binary) by stimulus length, across the stimulus conditions, compared to typical group mean scores.

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID	Mean 2 syll /4	Z score	Sig/not sig	Mean 3 syll /4	Z score	Sig/not sig
AJ4	3.00	-1.34	ns	.67	-2.99	p<0.01
DC4	1.00	-6.22	p<0.001	.00	-3.92	p<0.001
EW4						
JJ4	1.67	-4.49	p<0.001	.33	-3.46	p<0.001
LR4	2.33	-2.98	p<0.01	1.00	-2.53	p<0.01
MP4	3.00	-1.34	ns	1.33	-2.07	p<0.05
PG4	1.00	-6.22	p<0.001	.00	-3.92	p<0.001
SB4	1.00	-6.22	p<0.001	.00	-3.92	p<0.001
TB4	2.33	-2.98	p<0.01	1.67	-1.60	ns
TH4	1.00	-6.22	p<0.001	.00	-3.92	p<0.001
ChS5	3.33	-0.54	ns	3.00	0.25	ns
CS5	.67	-7.02	p<0.001	.00	-3.92	p<0.001
DG5	3.33	-0.54	ns	1.33	-2.07	p<0.05
EN5	2.67	-2.15	p<0.05	1.67	-1.60	ns
IF5	3.33	-0.54	ns	2.00	-1.14	ns
IT5	2.67	-2.15	p<0.05	.67	-2.99	p<0.01
JB5	2.33	-2.98	p<0.01	.67	-2.99	p<0.01
JC5	4.00	1.10	ns	3.67	1.18	ns
JK5	.67	-7.02	p<0.001	.67	-2.99	p<0.01
KK5	2.00	-3.78	p<0.001	.67	-2.99	p<0.01
KW5	1.67	-4.49	p<0.001	.67	-2.99	p<0.01
LS5	1.00	-6.22	p<0.001	.67	-2.99	p<0.01
OB5	3.00	-1.34	ns	.67	-2.99	p<0.01
OP5	1.67	-4.49	p<0.001	.00	-3.92	p<0.001
PBS5	4.00	1.10	ns	2.67	-0.21	ns
RB5	3.00	-1.34	ns	2.00	-1.14	ns
RH5	.33	-7.85	p<0.001	.00	-3.92	p<0.001
RW5	4.00	1.10	ns	2.67	-0.21	ns
SH5	3.67	0.29	ns	3.67	1.18	ns
TN5	3.00	-1.34	ns	1.00	-2.53	p<0.01
AG6	1.67	-4.49	p<0.001	.67	-2.99	p<0.01
CC6	2.67	-2.15	p<0.05	1.67	-1.60	ns
EC6	1.33	-5.41	p<0.001	.67	-2.99	p<0.01
HL6	1.33	-5.41	p<0.001	.33	-3.46	p<0.001
HM6	3.33	-0.54	ns	2.67	-0.21	ns
KH6	4.00	1.10	ns	3.33	0.71	ns
TC6	3.33	-0.54	ns	1.33	-2.07	p<0.05
TM6	3.33	-0.54	ns	.00	-3.92	p<0.001
JC7	4.00	1.10	ns	3.67	1.18	ns
SC7	3.00	-1.34	ns	2.33	-0.68	ns

Appendix 4.22 Individual clinical children: Five repetitions accuracy mean scores (PCC) by stimulus length, across the stimulus conditions, compared to typical group mean scores.

Key: z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID	Child's No.	Mean 2	Z score	Sig/not sig	Mean 3	Z score	Sig/not sig
AJ4	41	98.33	-0.04	ns	79.00	0.16	ns
DC4	42	55.33	-16.58	p<0.001	24.67	-15.30	p<0.001
EW4	43						
JJ4	44	85.00	-5.17	p<0.001	67.33	-6.18	p<0.001
LR4	45	87.67	-4.14	p<0.001	86.00	-2.19	p<0.05
MP4	46	87.00	-4.40	p<0.001	79.67	-3.54	p<0.001
PG4	47	48.33	-19.27	p<0.001	42.67	-11.45	p<0.001
SB4	48	47.67	-19.53	p<0.001	55.00	-8.82	p<0.001
TB4	49	91.33	-2.73	p<0.01	87.33	-1.91	p<0.05
TH4	50	61.00	-14.40	p<0.001	62.00	-7.32	p<0.001
ChS5	51	98.33	-0.04	ns	96.33	0.01	ns
CS5	52	41.00	-22.09	p<0.001	36.00	-12.88	p<0.001
DG5	53	91.67	-2.60	p<0.01	94.00	-0.48	ns
EN5	54	93.67	-1.83	p<0.05	90.67	-1.19	ns
IF5	55	95.00	-1.32	ns	91.00	-1.12	ns
IT5	56	74.00	-9.40	p<0.001	61.00	-7.53	p<0.001
JB5	57	97.33	-0.43	ns	70.67	-5.47	p<0.001
JC5	58	100.00	0.60	ns	97.33	0.23	ns
JK5	59	58.33	-15.43	p<0.001	71.00	-5.40	p<0.001
KK5	60	83.33	-5.81	p<0.001	54.33	-8.96	p<0.001
KW5	61	74.33	-9.27	p<0.001	78.00	-3.90	p<0.001
LS5	62	57.33	-15.81	p<0.001	64.00	-6.89	p<0.001
OB5	63	89.33	-3.50	p<0.001	80.33	-3.40	p<0.001
OP5	64	61.33	-14.27	p<0.001	62.00	-7.32	p<0.001
PBS5	65	100.00	0.60	ns	98.67	0.51	ns
RB5	66	87.67	-4.14	p<0.001	85.33	-2.34	p<0.01
RH5	67	51.67	-17.99	p<0.001	53.67	-9.10	p<0.001
RW5	68	100.00	0.60	ns	99.33	0.66	ns
SH5	69	100.00	0.60	ns	98.67	0.51	ns
TN5	70	100.00	0.60	ns	89.67	-1.41	ns
AG6	71	76.00	-8.63	p<0.001	71.33	-5.33	p<0.001
CC6	72	92.33	-2.35	p<0.01	88.00	-1.76	p<0.05
EC6	73	70.33	-10.81	p<0.001	71.67	-5.25	p<0.001
HL6	74	75.33	-8.89	p<0.001	75.33	-4.47	p<0.001
HM6	75	98.00	-0.17	ns	98.67	0.51	ns
KH6	76	100.00	0.60	ns	99.33	0.66	ns
TC6	77	95.67	-1.07	ns	82.33	-2.98	p<0.01
TM6	78	95.00	-1.32	ns	66.67	-6.32	p<0.001
JC7	79	100.00	0.60	ns	97.33	0.23	ns
SC7	80	96.00	-0.94	ns	88.67	-1.62	ns

Appendix 5.1. Clinical children: five repetitions raw consistency scores (binary) by stimulus condition (/8) and combined mean totals (/24).

Key: Child's ID =child's identification code; Child's no. =child's identification number

Child's ID	Child's No.	Real words /8	Non-words /8	Syllable sequences /8	Combined Total /24
AJ4	41	2.00	4.00	6.00	12.00
DC4	42	8.00	6.00	4.00	18.00
EW4	43	6.00	3.00		
JJ4	44	3.00	4.00	2.00	9.00
LR4	45	3.00	3.00	4.00	10.00
MP4	46	6.00	5.00	6.00	17.00
PG4	47	5.00	7.00	6.00	18.00
SB4	48	5.00	4.00	4.00	13.00
TB4	49	6.00	5.00	3.00	14.00
TH4	50	8.00	5.00	3.00	16.00
ChS5	51	8.00	7.00	4.00	19.00
CS5	52	2.00	.00	.00	2.00
DG5	53	7.00	4.00	6.00	17.00
EN5	54	5.00	4.00	4.00	13.00
IF5	55	7.00	5.00	5.00	17.00
IT5	56	5.00	6.00	6.00	17.00
JB5	57	6.00	4.00	3.00	14.00
JC5	58	8.00	8.00	7.00	23.00
JK5	59	4.00	3.00	4.00	11.00
KK5	60	4.00	2.00	2.00	8.00
KW5	61	5.00	4.00	4.00	13.00
LS5	62	3.00	6.00	3.00	12.00
OB5	63	5.00	4.00	4.00	13.00
OP5	64	2.00	4.00	5.00	11.00
PBS5	65	8.00	6.00	6.00	20.00
RB5	66	8.00	6.00	5.00	19.00
RH5	67	4.00	6.00	3.00	13.00
RW5	68	6.00	7.00	7.00	20.00
SH5	69	8.00	7.00	7.00	22.00
TN5	70	6.00	4.00	2.00	12.00
AG6	71	6.00	3.00	3.00	12.00
CC6	72	6.00	6.00	2.00	14.00
EC6	73	4.00	1.00	2.00	7.00
HL6	74	6.00	2.00	4.00	12.00
HM6	75	7.00	6.00	5.00	18.00
KH6	76	7.00	8.00	7.00	22.00
TC6	77	5.00	6.00	7.00	18.00
TM6	78	5.00	3.00	7.00	17.00
JC7	79	8.00	8.00	7.00	23.00
SC7	80	5.00	6.00	6.00	17.00

Appendix 5.2. Typical children: five repetitions raw consistency scores (binary) by stimulus condition (/8) and combined mean totals (/24).

Key: Child's ID =child's identification code; Child's no. =child's identification number

Child's ID	Child's No.	Real words /8	Non-words /8	Syllable sequences /8	Combined Total /24
AL4	1	6.00	5.00	7.00	18.00
An4	2	7.00	8.00	8.00	23.00
Ann4	3	8.00	8.00	7.00	23.00
Bel4	4	5.00	7.00	7.00	19.00
BN4	5	7.00	5.00	5.00	17.00
Is4	6	7.00	6.00	6.00	19.00
Ja4	7	7.00	5.00	7.00	19.00
Jo4	8	8.00	7.00	7.00	22.00
Ma4	9	5.00	6.00	7.00	18.00
Ni4	10	7.00	2.00	5.00	14.00
Re4	11	5.00	8.00	7.00	20.00
AB5	12	5.00	6.00	6.00	17.00
AL5	13	7.00	4.00	6.00	17.00
Anl5	14	8.00	8.00	7.00	23.00
Ao5	15	7.00	6.00	6.00	19.00
CE5	16	8.00	6.00	8.00	22.00
Da5	17	6.00	5.00	6.00	17.00
EL5	18	8.00	7.00	5.00	20.00
Ha5	19	4.00	5.00	6.00	15.00
Is5	20	7.00	7.00	7.00	21.00
Lo5	21	7.00	6.00	6.00	19.00
Ra5	22	5.00	8.00	5.00	18.00
Rh5	23	7.00			
Ro5	24	6.00	5.00	5.00	16.00
SO5	25	8.00	7.00	7.00	22.00
Ta5	26	8.00	8.00	7.00	23.00
Xa5	27	8.00	5.00	6.00	19.00
Za5	28	7.00	2.00	6.00	15.00
CM16	29	8.00	7.00	5.00	20.00
CM26	30	7.00	5.00	5.00	19.00
DK6	31	8.00	7.00	7.00	22.00
HM6	32	7.00	6.00	7.00	20.00
JM6	33	6.00	6.00	7.00	19.00
KB6	34	8.00	8.00	6.00	22.00
NB6	35	8.00	6.00	8.00	22.00
RS6	36	7.00	8.00	7.00	22.00
SB6	37	8.00	6.00	5.00	19.00
DQ7	38	7.00	7.00	7.00	21.00
DR7	39	6.00	7.00	5.00	18.00
EO7	40	5.00	8.00	7.00	20.00

Appendix 5.3. Individual clinical children: Five repetitions consistency total scores (binary), across the stimulus conditions, compared to the typical group mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number; z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level; M=mean; s.d. =standard deviation; sig. =significant; not sig.=not significant.

Child's ID	Child's No.	Totals /24	z score (M= 19.46; s.d. 2.39)	Sig./not sig
AJ4	41	12.00	-3.12	p<0.01
DC4	42	18.00	- 0.61	ns
EW4	43			
JJ4	44	9.00	-4.38	p<0.001
LR4	45	10.00	-3.96	p<0.001
MP4	46	17.00	-1.03	ns
PG4	47	18.00	- 0.61	ns
SB4	48	13.00	-2.70	p<0.01
TB4	49	14.00	-2.28	p<0.05
TH4	50	16.00	-1.45	ns
ChS5	51	19.00	0.19	ns
CS5	52	2.00	-7.31	p<0.001
DG5	53	17.00	-1.03	ns
EN5	54	13.00	-2.70	p<0.01
IF5	55	17.00	-1.03	ns
IT5	56	17.00	-1.03	ns
JB5	57	14.00	-2.28	p<0.05
JC5	58	23.00	1.48	ns
JK5	59	11.00	-3.54	p<0.001
KK5	60	8.00	-4.79	p<0.001
KW5	61	13.00	-2.70	p<0.01
LS5	62	12.00	-3.12	p<0.01
OB5	63	13.00	-2.70	p<0.01
OP5	64	11.00	-3.54	p<0.001
PBS5	65	20.00	0.23	ns
RB5	66	19.00	0.19	ns
RH5	67	13.00	-2.70	p<0.01
RW5	68	20.00	0.23	ns
SH5	69	22.00	1.06	ns
TN5	70	12.00	-3.12	p<0.01
AG6	71	12.00	-3.12	p<0.01
CC6	72	14.00	-2.28	p<0.05
EC6	73	7.00	-5.21	p<0.001
HL6	74	12.00	-3.12	p<0.01
HM6	75	18.00	- 0.61	ns
KH6	76	22.00	1.06	ns
TC6	77	18.00	- 0.61	ns
TM6	78	17.00	-1.03	ns
JC7	79	23.00	1.48	ns
SC7	80	17.00	-1.03	ns

Appendix 5.4. Clinical children: Consistency strength ratings (0-4) across the stimulus conditions.

Key: Child's ID =child's identification code; Child's no. =child's identification number rating 0=did not produce 5 repetitions; rating 1=repetition identical to child model; rating 2=repetition different to child model; rating 3= repetition different to 1 or 2; rating 4=repetition different to all previous repetitions.

Child's ID	Child's No.	Rating 0	Rating 1	Rating 2	Rating 3	Rating 4
AJ4	41	7.00	11.00	5.00	1.00	.00
DC4	42	6.00	18.00	.00	.00	.00
EW4	43					
JJ4	44	8.00	10.00	5.00	.00	1.00
LR4	45	12.00	11.00	1.00	.00	.00
MP4	46	2.00	17.00	3.00	1.00	1.00
PG4	47	2.00	18.00	2.00	1.00	1.00
SB4	48	3.00	14.00	5.00	2.00	.00
TB4	49	4.00	14.00	6.00	.00	.00
TH4	50	6.00	16.00	2.00	.00	.00
ChS5	51	3.00	20.00	1.00	.00	.00
CS5	52	14.00	2.00	3.00	1.00	4.00
DG5	53	1.00	16.00	6.00	1.00	.00
EN5	54	5.00	13.00	5.00	1.00	.00
IF5	55	2.00	18.00	3.00	1.00	.00
IT5	56	4.00	17.00	3.00	.00	.00
JB5	57	4.00	14.00	6.00	.00	.00
JC5	58	.00	23.00	.00	1.00	.00
JK5	59	2.00	15.00	6.00	1.00	.00
KK5	60	7.00	7.00	2.00	6.00	1.00
KW5	61	4.00	11.00	7.00	1.00	1.00
LS5	62	4.00	13.00	7.00	.00	.00
OB5	63	4.00	13.00	3.00	4.00	.00
OP5	64	.00	12.00	8.00	3.00	1.00
PBS5	65	4.00	20.00	.00	.00	.00
RB5	66	3.00	18.00	3.00	.00	.00
RH5	67	2.00	13.00	9.00	.00	.00
RW5	68	3.00	20.00	1.00	.00	.00
SH5	69	1.00	22.00	1.00	.00	.00
TN5	70	11.00	12.00	1.00	.00	.00
AG6	71	7.00	12.00	4.00	1.00	.00
CC6	72	5.00	14.00	4.00	1.00	.00
EC6	73	4.00	7.00	8.00	3.00	2.00
HL6	74	12.00	12.00	.00	.00	.00
HM6	75	3.00	18.00	3.00	.00	.00
KH6	76	1.00	22.00	1.00	.00	.00
TC6	77	1.00	18.00	3.00	2.00	.00
TM6	78	2.00	17.00	5.00	.00	.00
JC7	79	.00	23.00	1.00	.00	.00
SC7	80	3.00	16.00	3.00	1.00	1.00

Appendix 5.5. Typical children: Consistency strength ratings (0-4) across the stimulus conditions.

Key: Child's ID =child's identification code; Child's no. =child's identification number rating 0=did not produce 5 repetitions; rating 1=repetition identical to child model; rating 2=repetition different to child model; rating 3= repetition different to 1 or 2; rating 4=repetition different to all previous repetitions.

Child's ID	Child's No.	Rating 0	Rating 1	Rating 2	Rating 3	Rating 4
AL4	1	6.00	17.00	3.00	.00	.00
An4	2	1.00	23.00	1.00	.00	.00
Ann4	3	.00	23.00	.00	.00	.00
Bel4	4	4.00	19.00	2.00	1.00	.00
BN4	5	4.00	16.00	4.00	1.00	.00
Is4	6	3.00	19.00	2.00	1.00	.00
Ja4	7	3.00	19.00	2.00	1.00	.00
Jo4	8	2.00	22.00	1.00	.00	.00
Ma4	9	3.00	18.00	4.00	.00	.00
Ni4	10	9.00	14.00	2.00	.00	.00
Re4	11	2.00	20.00	1.00	.00	.00
AB5	12	4.00	16.00	1.00	1.00	.00
AL5	13	.00	14.00	1.00	2.00	.00
Anl5	14	.00	23.00	2.00	.00	.00
Ao5	15	1.00	20.00	1.00	1.00	.00
CE5	16	1.00	22.00	3.00	1.00	.00
Da5	17	.00	17.00	2.00	2.00	3.00
EL5	18	3.00	20.00	3.00	.00	.00
Ha5	19	2.00	14.00	1.00	2.00	.00
Is5	20	2.00	21.00	.00	.00	.00
Lo5	21	2.00	18.00	2.00	1.00	1.00
Ra5	22	4.00	18.00	4.00	1.00	.00
Rh5	23					
Ro5	24	5.00	16.00	2.00	.00	.00
SO5	25	1.00	22.00	1.00	.00	.00
Ta5	26	1.00	23.00	4.00	.00	.00
Xa5	27	3.00	19.00	2.00	.00	.00
Za5	28	4.00	16.00	1.00	.00	.00
CM16	29	2.00	20.00	1.00	.00	.00
CM26	30	5.00	17.00	1.00	.00	.00
DK6	31	1.00	22.00	2.00	.00	.00
HM6	32	.00	20.00	1.00	.00	.00
JM6	33	3.00	19.00	3.00	.00	.00
KB6	34	1.00	22.00	2.00	.00	.00
NB6	35	1.00	22.00	3.00	.00	.00
RS6	36	1.00	22.00	1.00	.00	.00
SB6	37	2.00	19.00	.00	1.00	.00
DQ7	38	2.00	21.00	2.00	.00	.00
DR7	39	3.00	18.00	4.00	.00	.00
EO7	40	1.00	20.00	2.00	1.00	.00

Appendix 5.6. Clinical children (n=40): five repetitions consistency raw **scores (binary) by stimulus length (2 vs. 3 syllables) and total mean scores.**

Key: Child's ID =child's identification code; Child's no. =child's identification number

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AJ4	2.00	.00	3.00	1.00	4.00	2.00	3.00	1.00
DC4	4.00	4.00	2.00	4.00	2.00	2.00	2.67	3.33
EW4	4.00	2.00	2.00	1.00				
JJ4	2.00	1.00	3.00	1.00	1.00	1.00	2.00	1.00
LR4	2.00	1.00	1.00	2.00	3.00	1.00	2.00	1.33
MP4	4.00	2.00	4.00	1.00	3.00	3.00	3.67	2.00
PG4	3.00	2.00	4.00	3.00	3.00	3.00	3.33	2.67
SB4	3.00	2.00	3.00	1.00	3.00	1.00	3.00	1.33
TB4	4.00	2.00	1.00	4.00	2.00	1.00	2.33	2.33
TH4	4.00	4.00	2.00	3.00	1.00	2.00	2.33	3.00
ChS5	4.00	4.00	3.00	4.00	3.00	1.00	3.33	3.00
CS5	2.00	.00	.00	.00	.00	.00	.67	.00
DG5	4.00	3.00	3.00	1.00	4.00	2.00	3.67	2.00
EN5	3.00	2.00	3.00	1.00	2.00	2.00	2.67	1.67
IF5	4.00	3.00	3.00	2.00	3.00	2.00	3.33	2.33
IT5	3.00	2.00	4.00	2.00	3.00	3.00	3.33	2.33
JB5	4.00	2.00	1.00	3.00	2.00	1.00	2.33	2.00
JC5	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
JK5	3.00	1.00	2.00	1.00	3.00	1.00	2.67	1.00
KK5	3.00	1.00	1.00	1.00	2.00	.00	2.00	.67
KW5	3.00	2.00	3.00	1.00	3.00	1.00	3.00	1.33
LS5	3.00	.00	3.00	3.00	1.00	2.00	2.33	1.67
OB5	4.00	1.00	1.00	3.00	3.00	1.00	2.67	1.67
OP5	2.00	.00	4.00	.00	3.00	2.00	3.00	.67
PBS5	4.00	4.00	4.00	2.00	4.00	2.00	4.00	2.67
RB5	4.00	4.00	4.00	2.00	3.00	2.00	3.67	2.67
RH5	3.00	1.00	2.00	4.00	2.00	1.00	2.33	2.00
RW5	4.00	2.00	4.00	3.00	4.00	3.00	4.00	2.67
SH5	4.00	4.00	3.00	4.00	4.00	3.00	3.67	3.67
TN5	4.00	2.00	3.00	1.00	2.00	.00	3.00	1.00
AG6	3.00	3.00	2.00	1.00	2.00	1.00	2.33	1.67
CC6	4.00	2.00	3.00	3.00	2.00	.00	3.00	1.67
EC6	3.00	1.00	1.00	.00	1.00	1.00	1.67	.67
HL6	4.00	2.00	1.00	1.00	3.00	1.00	2.67	1.33
HM6	4.00	3.00	2.00	4.00	4.00	1.00	3.33	2.67
KH6	4.00	3.00	4.00	4.00	4.00	1.00	4.00	2.67
TC6	3.00	2.00	3.00	3.00	4.00	3.00	3.33	2.67
TM6	4.00	1.00	3.00	.00	3.00	4.00	3.33	1.67
JC7	4.00	4.00	4.00	4.00	3.00	4.00	3.67	4.00
SC7	3.00	2.00	3.00	3.00	4.00	2.00	3.33	2.33

Appendix 5.7. Typical children (n=40): five repetitions consistency raw scores (binary) by stimulus length (2 vs. 3 syllables) and total mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2	Mean 3
AL4	4.00	2.00	3.00	2.00	4.00	3.00	3.67	2.33
An4	3.00	4.00	4.00	4.00	4.00	4.00	3.67	4.00
Ann4	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
Bel4	2.00	3.00	3.00	4.00	4.00	3.00	3.00	3.33
BN4	4.00	3.00	3.00	2.00	4.00	1.00	3.67	2.00
Is4	4.00	3.00	4.00	2.00	4.00	2.00	4.00	2.33
Ja4	4.00	3.00	3.00	2.00	4.00	3.00	3.67	2.67
Jo4	4.00	4.00	4.00	3.00	4.00	3.00	4.00	3.33
Ma4	2.00	3.00	4.00	2.00	3.00	4.00	3.00	3.00
Ni4	4.00	3.00	1.00	1.00	4.00	1.00	3.00	1.67
Re4	3.00	2.00	4.00	4.00	4.00	3.00	3.67	3.00
AB5	3.00	2.00	4.00	2.00	3.00	3.00	3.33	2.33
AL5	4.00	3.00	2.00	2.00	4.00	2.00	3.33	2.33
Anl5	4.00	4.00	4.00	4.00	3.00	4.00	3.67	4.00
Ao5	4.00	3.00	4.00	2.00	3.00	3.00	3.67	2.67
CE5	4.00	4.00	4.00	2.00	4.00	4.00	4.00	3.33
Da5	4.00	2.00	3.00	2.00	4.00	2.00	3.67	2.00
EL5	4.00	4.00	4.00	3.00	3.00	2.00	3.67	3.00
Ha5	3.00	1.00	2.00	3.00	4.00	2.00	3.00	2.00
Is5	4.00	3.00	3.00	4.00	4.00	3.00	3.67	3.33
Lo5	4.00	3.00	4.00	2.00	4.00	2.00	4.00	2.33
Ra5	4.00	1.00	4.00	4.00	4.00	1.00	4.00	2.00
Rh5	4.00	3.00						
Ro5	4.00	2.00	3.00	2.00	3.00	2.00	3.33	2.00
SO5	4.00	4.00	4.00	3.00	4.00	3.00	4.00	3.33
Ta5	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.67
Xa5	4.00	4.00	3.00	2.00	3.00	3.00	3.33	3.00
Za5	4.00	3.00	.00	2.00	4.00	2.00	2.67	2.33
CM16	4.00	4.00	3.00	4.00	3.00	2.00	3.33	3.33
CM26	4.00	3.00	3.00	2.00	3.00	2.00	3.33	2.33
DK6	4.00	4.00	3.00	4.00	3.00	4.00	3.33	4.00
HM6	4.00	3.00	3.00	3.00	4.00	3.00	3.67	3.00
JM6	4.00	2.00	3.00	3.00	4.00	3.00	3.67	2.67
KB6	4.00	4.00	4.00	4.00	4.00	2.00	4.00	3.33
NB6	4.00	4.00	4.00	2.00	4.00	4.00	4.00	3.33
RS6	4.00	3.00	4.00	4.00	4.00	3.00	4.00	3.33
SB6	4.00	4.00	2.00	4.00	3.00	2.00	3.00	3.33
DQ7	4.00	3.00	4.00	3.00	4.00	3.00	4.00	3.00
DR7	2.00	4.00	4.00	3.00	3.00	2.00	3.00	3.00
EO7	3.00	2.00	4.00	4.00	4.00	3.00	3.67	3.00

Appendix 5.8. Individual clinical children: Five repetitions individual consistency mean scores (binary) by stimulus length, across the stimulus conditions, compared to typical group mean scores.

Key: Child's ID =child's identification code; Child's no. =child's identification number; Mean 2=mean for 2 syllable targets; Mean 3=mean for 3 syllable targets; z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level; sig=significant; not sig.=not significant.

Child's ID	Child's No.	Mean 2	Z score	Sig./ not sig.	Mean 3	Z score	Sig./not sig.
AJ4	41	3.00	-1.53	ns.	1.00	-3.05	p<0.01
DC4	42	2.67	-2.39	p<0.01	3.33	0.71	ns.
EW4	43						
JJ4	44	2.00	-4.16	p<0.001	1.00	-3.05	p<0.01
LR4	45	2.00	-4.16	p<0.001	1.33	-2.52	p<0.01
MP4	46	3.67	0.24	ns.	2.00	-1.44	ns.
PG4	47	3.33	-0.66	ns.	2.67	-0.35	ns.
SB4	48	3.00	-1.53	ns.	1.33	-2.52	p<0.01
TB4	49	2.33	-3.29	p<0.001	2.33	-0.90	ns.
TH4	50	2.33	-3.29	p<0.001	3.00	0.18	ns.
ChS5	51	3.33	-0.66	ns.	3.00	0.18	ns.
CS5	52	.67	-7.66	p<0.001	.00	-4.66	p<0.001
DG5	53	3.67	0.24	ns.	2.00	-1.44	ns.
EN5	54	2.67	-2.39	p<0.01	1.67	-1.97	p<0.05
IF5	55	3.33	-0.66	ns.	2.33	-0.90	ns.
IT5	56	3.33	-0.66	ns.	2.33	-0.90	ns.
JB5	57	2.33	-3.29	p<0.001	2.00	-1.44	ns.
JC5	58	4.00	1.11	ns.	3.67	1.26	ns.
JK5	59	2.67	-2.39	p<0.01	1.00	-3.05	p<0.01
KK5	60	2.00	-4.16	p<0.001	.67	-3.58	p<0.001
KW5	61	3.00	-1.53	ns.	1.33	-2.52	p<0.01
LS5	62	2.33	-3.29	p<0.001	1.67	-1.97	p<0.05
OB5	63	2.67	-2.39	p<0.01	1.67	-1.97	p<0.05
OP5	64	3.00	-1.53	ns.	.67	-3.58	p<0.001
PBS5	65	4.00	1.11	ns.	2.67	-0.35	ns.
RB5	66	3.67	0.24	ns.	2.67	-0.35	ns.
RH5	67	2.33	-3.29	p<0.001	2.00	-1.44	ns.

Child's ID	Child's No.	Mean 2	Z score	Sig./ not sig.	Mean 3	Z score	Sig./not sig.
SH5	69	3.67	0.24	ns.	3.67	1.26	ns.
TN5	70	3.00	-1.53	ns.	1.00	-3.05	p<0.01
AG6	71	2.33	-3.29	p<0.001	1.67	-1.97	p<0.05
CC6	72	3.00	-1.53	ns.	1.67	-1.97	p<0.05
EC6	73	1.67	-5.03	p<0.001	.67	-3.58	p<0.001
HL6	74	2.67	-2.39	p<0.01	1.33	-2.52	p<0.01
HM6	75	3.33	-0.66	ns.	2.67	-0.35	ns.
KH6	76	4.00	1.11	ns.	2.67	-0.35	ns.
TC6	77	3.33	-0.66	ns.	2.67	-0.35	ns.
TM6	78	3.33	-0.66	ns.	1.67	-1.97	p<0.05
JC7	79	3.67	0.24	ns.	4.00	1.79	p<0.05*
SC7	80	3.33	-0.66	ns.	2.33	-0.90	ns.

Appendix 6.1. Clinical children: Rate of five repetitions of DDK targets: raw scores (secs/syll), by stimulus condition and mean rate across the conditions.
Key: secs/syll=seconds per syllable; Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child' No.	Real words	Non words	Syllable sequences	Mean rate
AJ4	41	.31	.34	.32	.32
DC4	42	.29	.28	.28	.28
EW4	43	.33	.39		
JJ4	44	.34	.32	.39	.35
LR4	45	.25	.33	.28	.29
MP4	46	.33	.32	.42	.36
PG4	47	.25	.26	.26	.26
SB4	48	.36	.33	.26	.31
TB4	49	.28	.29	.29	.29
TH4	50	.29	.33	.39	.34
ChS5	51	.24	.23	.24	.24
CS5	52	.53	.53	.60	.55
DG5	53	.20	.22	.24	.22
EN5	54	.29	.35	.29	.31
IF5	55	.42	.42	.38	.41
IT5	56	.38	.40	.39	.39
JB5	57	.32	.30	.28	.30
JC5	58	.27	.30	.25	.27
JK5	59	.23	.22	.26	.24
KK5	60	.27	.24	.29	.27
KW5	61	.30	.39	.34	.34
LS5	62	.32	.39	.30	.33
OB5	63	.29	.37	.30	.32
OP5	64	.25	.27	.27	.26
PBS5	65	.31	.28	.26	.28
RB5	66	.29	.36	.33	.33
RH5	67	.24	.26	.29	.26
RW5	68	.23	.32	.21	.25
SH5	69	.30	.31	.27	.29
TN5	70	.29	.31	.34	.31
AG6	71	.23	.25	.24	.24
CC6	72	.25	.23	.28	.25
EC6	73	.35	.35	.36	.35
HL6	74	.26	.26	.23	.25
HM6	75	.18	.20	.20	.19
KH6	76	.24	.27	.23	.24
TC6	77	.37	.49	.43	.43
TM6	78	.30	.26	.25	.27
JC7	79	.26	.41	.32	.33
SC7	80	.35	.37	.36	.36

Appendix 6.2 Typical children: Rate of five repetitions of DDK targets: raw scores (secs/syll), by stimulus condition and mean rate across the conditions.

Key: secs/syll=seconds per syllable; Child's ID =child's identification code; Child's no. =child's identification number.

Child's ID	Child' No.	Real words	Non words	Syllable sequences	Mean rate
AL4	1	.24	.28	.23	.25
An4	2	.22	.25	.23	.23
Ann4	3	.24	.27	.23	.25
Bel4	4	.22	.23	.27	.24
BN4	5	.18	.20	.18	.19
Is4	6	.33	.32	.28	.31
Ja4	7	.20	.22	.19	.20
Jo4	8	.33	.37	.30	.33
Ma4	9	.25	.26	.23	.25
Ni4	10	.25	.29	.23	.26
Re4	11	.26	.27	.26	.26
AB5	12	.23	.23	.25	.24
AL5	13	.21	.20	.20	.20
Anl5	14	.24	.27	.23	.25
Ao5	15	.27	.28	.26	.27
CE5	16	.25	.26	.22	.24
Da5	17	.17	.18	.18	.17
EL5	18	.21	.25	.25	.24
Ha5	19	.22	.26	.23	.24
Is5	20	.25	.26	.23	.25
Lo5	21	.32	.37	.32	.34
Ra5	22	.17	.18	.15	.17
Rh5	23	.25			
Ro5	24	.20	.22	.20	.21
SO5	25	.26	.24	.24	.25
Ta5	26	.24	.26	.25	.25
Xa5	27	.30	.28	.29	.29
Za5	28	.25	.37	.30	.31
CM16	29	.22	.23	.20	.22
CM26	30	.21	.20	.21	.21
DK6	31	.18	.19	.17	.18
HM6	32	.17	.20	.15	.17
JM6	33	.20	.18	.17	.18
KB6	34	.19	.20	.18	.19
NB6	35	.22	.23	.23	.22
RS6	36	.21	.24	.19	.21
SB6	37	.21	.25	.19	.22
DQ7	38	.18	.23	.21	.21
DR7	39	.18	.18	.15	.17
EO7	40	.19	.20	.19	.20

Appendix 6.3. Individual clinical children's rates (secs/syll) compared to the typical group's mean rates, by stimulus condition

Key: secs/syll.=seconds per syllable; z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level

Child's ID	Child's No.	Mean rate	Z score	Sig./not sig.
AJ4	41	.32	2.25	p<0.05
DC4	42	.28	1.25	ns
EW4	43			
JJ4	44	.35	3.00	p<0.01
LR4	45	.29	1.50	ns
MP4	46	.36	3.25	p<0.01
PG4	47	.26	0.75	ns
SB4	48	.31	2.00	p<0.05
TB4	49	.29	1.50	ns
TH4	50	.34	2.75	p<0.01
ChS5	51	.24	0.01	ns
CS5	52			
DG5	53	.22	-0.25	ns
EN5	54	.31	2.00	p<0.05
IF5	55	.41	4.50	p<0.001
IT5	56	.39	4.00	p<0.001
JB5	57	.30	1.75	p<0.05
JC5	58	.27	1.00	ns
JK5	59	.24	0.01	ns
KK5	60	.27	1.00	ns
KW5	61	.34	2.75	p<0.01
LS5	62	.33	2.50	p<0.01
OB5	63	.32	2.25	p<0.05
OP5	64	.26	0.75	ns
PBS5	65	.28	1.25	ns
RB5	66	.33	2.50	p<0.01
RH5	67	.26	0.75	ns
RW5	68	.25	0.50	ns
SH5	69	.29	1.50	ns

Child's ID	Child's No.	Mean rate	Z score	Sig./not sig.
AG6	71	.24	0.01	ns
CC6	72	.25	0.50	ns
EC6	73	.35	3.00	p<0.01
HL6	74	.25	0.50	ns
HM6	75	.19	-1.00	ns
KH6	76	.24	0.01	ns
TC6	77	.43	5.00	p<0.001
TM6	78	.27	1.00	ns
JC7	79	.33	2.50	p<0.01
SC7	80	.36	3.25	p<0.01

Appendix 6.4. Clinical children: Rate of five repetitions of DDK targets (secs/syll): raw scores by stimulus length in each condition and mean rates.

Key: secs/syll =seconds per syllable; Child's ID =child's identification code; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean rate 2=mean rate for 2 syllable targets across conditions; Mean rate 3=mean rate for 3 syllable targets across conditions.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean rate 2	Mean rate 3
AJ4	.32	.29	.38	.29	.35	.28	.35	.29
DC4	.28	.31	.25	.30	.26	.30	.26	.30
EW4	.40	.26	.46	.32				
JJ4	.35	.33	.31	.32	.37	.41	.35	.35
LR4	.24	.26	.28	.37	.27	.29	.26	.31
MP4	.31	.35	.27	.37	.41	.42	.33	.38
PG4	.24	.26	.22	.31	.25	.27	.24	.28
SB4	.22	.49	.23	.42	.21	.32	.22	.41
TB4	.23	.33	.30	.29	.30	.28	.28	.30
TH4	.30	.28	.36	.30	.38	.40	.35	.33
ChS5	.23	.25	.23	.24	.24	.23	.23	.24
CS5	.52	.55	.46	.60	.60		.53	
DG5	.19	.21	.21	.23	.26	.22	.22	.22
EN5	.24	.33	.37	.34	.25	.33	.28	.33
IF5	.42	.42	.39	.45	.38	.39	.39	.42
IT5	.36	.39	.43	.37	.41	.38	.40	.38
JB5	.31	.33	.28	.31	.29	.28	.29	.31
JC5	.27	.28	.28	.31	.23	.26	.26	.28
JK5	.20	.27	.17	.27	.24	.29	.20	.28
KK5	.24	.30	.24	.25	.30	.28	.26	.28
KW5	.31	.29	.38	.40	.36	.32	.35	.34
LS5	.31	.32	.35	.42	.38	.22	.35	.32
OB5	.25	.32	.37	.37	.28	.33	.30	.34
OP5	.27	.23	.28	.26	.29	.25	.28	.24
PBS5	.29	.33	.26	.30	.25	.26	.27	.30
RB5	.25	.33	.32	.41	.31	.35	.29	.36
RH5	.23	.25	.24	.28	.26	.31	.24	.28
RW5	.21	.25	.30	.35	.22	.19	.24	.26
SH5	.27	.33	.27	.35	.26	.29	.27	.32
TN5	.24	.34	.33	.30	.36	.31	.31	.32
AG6	.24	.22	.25	.26	.24	.23	.24	.24
CC6	.23	.28	.21	.25	.26	.30	.23	.27
EC6	.35	.36	.37	.34	.34	.38	.35	.36
HL6	.27	.25	.26	.26	.23	.24	.25	.25
HM6	.17	.18	.19	.21	.20	.20	.19	.20
KH6	.22	.26	.24	.30	.23	.23	.23	.26
TC6	.34	.40	.52	.47	.40	.46	.42	.44
TM6	.30	.30	.24	.28	.25	.25	.26	.28
JC7	.26	.26	.36	.45	.33	.31	.32	.34
SC7	.34	.36	.28	.47	.37	.35	.33	.39

Appendix 6.5. Typical children: Rate of five repetitions of DDK targets (secs/syll): raw scores by stimulus length in each condition and mean rates.

Key: secs/syll =seconds per syllable; Child's ID =child's identification code; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean rate 2=mean rate for 2 syllable targets across conditions; Mean rate 3=mean rate for 3 syllable targets across conditions.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean rate 2	Mean rate 3
AL4	.23	.25	.29	.28	.25	.21	.26	.25
An4	.21	.23	.25	.26	.23	.23	.23	.24
Ann4	.24	.24	.30	.25	.25	.21	.26	.23
Bel4	.19	.24	.21	.26	.29	.24	.23	.25
BN4	.17	.20	.18	.21	.17	.20	.17	.20
Is4	.40	.27	.36	.28	.34	.23	.37	.26
Ja4	.19	.20	.20	.23	.17	.20	.19	.21
Jo4	.34	.32	.39	.35	.32	.27	.35	.31
Ma4	.24	.26	.26	.26	.23	.24	.24	.26
Ni4	.28	.22	.29	.29	.25	.22	.27	.24
Re4	.26	.27	.27	.26	.29	.23	.27	.25
AB5	.22	.25	.22	.25	.26	.25	.23	.25
AL5	.17	.26	.18	.23	.19	.21	.18	.23
Anl5	.23	.25	.25	.28	.23	.24	.23	.26
Ao5	.29	.25	.31	.24	.27	.25	.29	.25
CE5	.28	.22	.23	.28	.23	.21	.25	.24
Da5	.15	.18	.17	.18	.18	.18	.17	.18
EL5	.20	.23	.22	.28	.26	.25	.22	.25
Ha5	.21	.24	.26	.26	.23	.24	.23	.24
Is5	.27	.23	.27	.25	.25	.21	.26	.23
Lo5	.31	.34	.33	.41	.33	.31	.32	.35
Ra5	.16	.18	.18	.18	.13	.18	.15	.18
Rh5	.27	.23						
Ro5	.20	.20	.21	.23	.18	.22	.20	.22
SO5	.28	.25	.24	.24	.27	.21	.27	.23
Ta5	.26	.22	.26	.27	.28	.22	.26	.24
Xa5	.34	.27	.28	.27	.32	.26	.31	.27
Za5	.24	.26	.41	.34	.29	.30	.31	.30
CM16	.22	.22	.25	.21	.19	.21	.22	.21
CM26	.21	.22	.20	.21	.24	.18	.22	.20
DK6	.17	.19	.19	.18	.16	.19	.18	.18
HM6	.16	.18	.19	.21	.17	.13	.17	.17
JM6	.17	.22	.15	.21	.15	.20	.15	.21
KB6	.19	.20	.19	.22	.16	.20	.18	.21
NB6	.22	.21	.24	.22	.23	.22	.23	.22
RS6	.20	.22	.22	.25	.18	.19	.20	.22
SB6	.21	.22	.26	.23	.19	.19	.22	.21
DQ7	.17	.19	.22	.24	.22	.19	.21	.21
DR7	.17	.20	.16	.21	.15	.16	.16	.19
EO7	.17	.21	.19	.22	.19	.19	.18	.21

Appendix 6.6 Individual clinical children's rates (secs/syll) compared to the typical group's mean rates, by stimulus length

Key: secs/syll=syllables per seconds= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child's ID	Child's No.	2 syll	Z score	Sig./ not sig.	3 syll	Z score	Sig./ not sig.
AJ4	41	.35	2.40	p<0.01	.29	1.50	ns
DC4	42	.26	0.06	ns	.30	1.75	p<0.05
EW4	43						
JJ4	44	.35	2.40	p<0.01	.35	3.00	p<0.01
LR4	45	.26	0.60	ns	.31	2.00	p<0.05
MP4	46	.33	2.00	p<0.05	.38	3.75	p<0.001
PG4	47	.24	0.20	ns	.28	1.25	ns
SB4	48	.22	-0.20	ns	.41	4.50	p<0.001
TB4	49	.28	1.00	ns	.30	1.75	p<0.05
TH4	50	.35	2.40	p<0.01	.33	2.50	p<0.01
CHS5	51	.23	0	ns	.24	0.25	ns
CS5	52	.53	6.00	p<0.001			
DG5	53	.22	-0.20	ns	.22	-0.25	ns
EN5	54	.28	1.00	ns	.33	2.50	p<0.01
IF5	55	.39	3.20	p<0.01	.42	4.75	p<0.001
IT5	56	.40	3.40	p<0.001	.38	3.75	p<0.001
JB5	57	.29	1.20	ns	.31	2.00	p<0.05
JC5	58	.26	0.60	ns	.28	1.25	ns
JK5	59	.20	-0.60	ns	.28	1.25	ns
KK5	60	.26	0.60	ns	.28	1.25	ns
KW5	61	.35	2.40	p<0.01	.34	2.75	p<0.01
LS5	62	.35	2.40	p<0.01	.32	2.25	p<0.05
OB5	63	.30	1.40	ns	.34	2.75	p<0.01
OP5	64	.28	1.00	ns	.24	0.25	ns
PBS5	65	.27	0.80	ns	.30	1.75	p<0.05
RB5	66	.29	1.20	ns	.36	3.25	p<0.01
RH5	67	.24	0.20	ns	.28	1.25	ns

Child's ID	Child's No.	2 syll	Z score	Sig./ not sig.	3 syll	Z score	Sig./ not sig.
SH5	69	.29	1.20	ns	.27	1.00	ns
TN5	70	.31	1.60	ns	.31	2.00	p<0.05
AG6	71	.24	0.20	ns	.24	0.25	ns
CC6	72	.23	0	ns	.27	1.00	ns
EC6	73	.35	2.40	p<0.01	.36	3.25	p<0.01
HL6	74	.25	0.40	ns	.25	0.50	ns
HM6	75	.19	-0.80	ns	.20	-0.75	ns
KH6	76	.23	0	ns	.26	0.75	ns
TC6	77	.42	3.80	p<0.001	.44	5.25	p<0.001
TM6	78	.26	0.60	ns	.28	1.25	ns
JC7	79	.32	1.80	p<0.05	.34	2.75	p<0.01
SC7	80	.33	2.00	p<0.05	.39	4.00	p<0.001

Appendix 6.7. Clinical children: Mean number of repetitions by stimulus length in each condition and the mean number of repetitions by stimulus length.

Key: Child's ID =child's identification code; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean no. of repetitions for 2 syllable targets across conditions; Mean 3=mean no. of repetitions for 3 syllable targets across conditions.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2 No. reps	Mean 3 No. reps
AJ4	5.00	4.00	5.00	5.00	5.00	5.00	5.00	4.6
DC4	5.00	5.00	4.75	4.25	4.25	4.67	4.67	4.64
EW4	5.00	4.67	4.75					
JJ4	4.50	4.50	5.00	4.25	4.25	4.50	4.58	4.42
LR4	4.75	4.00	4.50	5.00	5.00	4.25	4.75	4.42
MP4	5.00	5.00	5.00	5.00	5.00	4.50	5.00	4.83
PG4	5.00	4.50	5.00	4.75	4.75	5.00	4.92	4.75
SB4	5.00	5.00	5.00	5.00	5.00	4.75	5.00	4.92
TB4	5.00	4.75	4.63	4.75	4.75	4.75	4.79	4.75
TH4	5.00	5.00	5.00	4.25	4.25	4.50	4.75	4.58
ChS5	5.00	5.00	4.75	5.00	5.00	4.50	4.92	4.83
CS5	5.00	4.00	5.00	4.00	4.00		4.67	
DG5	5.00	5.00	5.00	5.00	5.00	4.67	5.00	4.89
EN5	4.75	4.75	5.00	5.00	5.00	4.75	4.92	4.83
IF5	5.00	5.00	4.75	5.00	5.00	4.75	4.92	4.92
IT5	5.00	4.33	5.00	4.75	4.75	5.00	4.92	4.69
JB5	5.00	5.00	4.75	4.75	4.75	4.75	4.83	4.83
JC5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
JK5	4.75	5.00	5.00	5.00	5.00	4.75	4.92	4.92
KK5	5.00	4.25	5.00	4.63	5.00	5.00	5.00	4.63
KW5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
LS5	4.75	4.25	5.00	5.00	5.00	5.00	4.92	4.75
OB5	5.00	4.25	4.50	5.00	5.00	5.00	4.83	4.75
OP5	5.00	4.75	5.00	5.00	5.00	4.75	5.00	4.83
PBS5	5.00	5.00	5.00	5.00	5.00	4.25	5.00	4.75
RB5	5.00	4.50	5.00	5.00	5.00	4.75	5.00	4.75
RH5	5.00	5.00	5.00	5.00	5.00	4.75	5.00	4.92
RW5	5.00	4.25	5.00	5.00	5.00	4.75	5.00	4.67
SH5	5.00	5.00	4.75	5.00	5.00	5.00	4.92	5.00
TN5	5.00	4.25	5.00	4.50	4.50	4.00	4.83	4.25
AG6	5.00	4.75	4.50	5.00	5.00	5.00	4.83	4.92
CC6	5.00	4.75	5.00	4.75	4.75	4.25	4.92	4.58
EC6	4.75	4.75	5.00	4.67	4.67	5.00	4.81	4.81
HL6	5.00	4.50	4.25	4.50	4.50	4.25	4.58	4.42
HM6	5.00	5.00	5.00	5.00	5.00	4.67	5.00	4.89
KH6	5.00	5.00	5.00	5.00	5.00	4.75	5.00	4.92
TC6	4.75	4.50	5.00	5.00	5.00	5.00	4.92	4.83
TM6	5.00	4.75	4.75	5.00	5.00	5.00	4.92	4.92
JC7	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
SC7	4.75	4.75	4.75	5.00	5.00	4.75	4.83	4.83

Appendix 6.8. Typical children: Mean number of repetitions by stimulus length in each condition and the mean number of repetitions by stimulus length.

Key: Child's ID =child's identification code; RW2=2 syllable real words; RW3=3 syllable real words; NW2=2 syllable non-words; NW3=3 syllable non-words; SS2=2 syllable. Syllable sequences; SS3=3 syllable, syllable sequences; Mean 2=mean no. of repetitions for 2 syllable targets across conditions; Mean 3=mean no. of repetitions for 3 syllable targets across conditions.

Child's ID	RW2	RW3	NW2	NW3	SS2	SS3	Mean 2 No. reps.	Mean 3 No. reps.
AL4	5.00	4.50	5.00	5.00	5.00	4.50	5.00	4.67
An4	4.75	5.00	5.00	5.00	5.00	5.00	4.92	5.00
Ann4	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Bel4	4.25	5.00	4.25	5.00	5.00	5.00	4.50	5.00
BN4	5.00	5.00	4.75	5.00	5.00	5.00	4.92	5.00
Is4	5.00	5.00	5.00	5.00	5.00	4.50	5.00	4.83
Ja4	5.00	4.75	4.75	5.00	5.00	5.00	4.92	4.92
Jo4	5.00	5.00	4.75	5.00	5.00	4.75	4.92	4.92
Ma4	4.50	5.00	5.00	4.75	4.75	5.00	4.75	4.92
Ni4	5.00	4.75	4.50	5.00	5.00	4.00	4.83	4.58
Re4	4.75	4.75	5.00	5.00	5.00	5.00	4.92	4.92
AB5	4.75	4.75	5.00	4.75	4.75	5.00	4.83	4.83
AL5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Anl5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Ao5	5.00	5.00	5.00	4.75	4.75	5.00	4.92	4.92
CE5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Da5	5.00	4.75	5.00	5.00	5.00	5.00	5.00	4.92
EL5	5.00	5.00	5.00	4.75	4.75	4.50	4.92	4.75
Ha5	4.75	4.50	5.00	5.00	5.00	5.00	4.92	4.83
Is5	5.00	4.75	5.00	5.00	5.00	5.00	5.00	4.92
Lo5	4.75	5.00	5.00	5.00	5.00	5.00	4.92	5.00
Ra5	5.00	4.00	5.00	5.00	5.00	4.67	5.00	4.56
Rh5	5.00	4.75						
Ro5	5.00	5.00	5.00	5.00	5.00	4.33	5.00	4.78
SO5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Ta5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Xa5	5.00	5.00	4.75	5.00	5.00	5.00	4.92	5.00
Za5	4.75	5.00	5.00	5.00	5.00	4.75	4.92	4.92
CM16	5.00	5.00	5.00	4.50	4.50	4.25	4.83	4.58
CM26	5.00	5.00	4.75	4.75	4.75	4.50	4.83	4.75
DK6	5.00	5.00	5.00	4.75	4.75	5.00	4.92	4.92
HM6	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
JM6	5.00	5.00	4.75	5.00	5.00	4.75	4.92	4.92
KB6	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
NB6	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
RS6	5.00	5.00	5.00	5.00	5.00	4.75	5.00	4.92
SB6	5.00	5.00	4.75	5.00	5.00	4.75	4.92	4.92
DQ7	5.00	4.75	5.00	5.00	5.00	4.75	5.00	4.83
DR7	4.75	5.00	5.00	4.75	4.75	4.75	4.83	4.83
EO7	5.00	5.00	5.00	5.00	5.00	4.75	5.00	4.92

Appendix 7.1: Clinical children (n=40): DDK Accuracy and DDK Consistency total scores (binary scoring), compared to the typical group mean scores.

Key: A=Accuracy; R=Rate; ns =not significant; sig.=significant; not sig; =not significant; z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level. *=EW4 did not complete all subtests.

Child's ID	Child's No.	Accuracy Total /24	Z score	Sig/not sig	Consistency Total /24	Z score	Sig/not sig
AJ4	41	11.00	-2.96	p<0.01	12.00	-3.12	p<0.01
DC4	42	3.00	-5.87	p<0.001	18.00	- 0.61	ns
EW4	43	*			*		
JJ4	44	6.00	-4.77	p<0.001	9.00	-4.38	p<0.001
LR4	45	10.00	-3.32	p<0.001	10.00	-3.96	p<0.001
MP4	46	13.00	-2.23	p<0.05	17.00	-1.03	ns
PG4	47	3.00	-5.87	p<0.001	18.00	- 0.61	ns
SB4	48	3.00	-5.87	p<0.001	13.00	-2.70	p<0.01
TB4	49	12.00	-2.59	p<0.01	14.00	-2.28	p<0.05
TH4	50	3.00	-5.87	p<0.001	16.00	-1.45	ns
ChS5	51	19.00	-0.05	ns	19.00	0.19	ns
CS5	52	2.00	-6.23	p<0.001	2.00	-7.31	p<0.001
DG5	53	14.00	-1.87	p<0.05	17.00	-1.03	ns
EN5	54	13.00	-2.23	p<0.05	13.00	-2.70	p<0.01
IF5	55	16.00	-1.14	ns	17.00	-1.03	ns
IT5	56	10.00	-3.32	p<0.001	17.00	-1.03	ns
JB5	57	9.00	-3.68	p<0.001	14.00	-2.28	p<0.05
JC5	58	23.00	1.41	ns	23.00	1.48	ns
JK5	59	3.00	-5.87	p<0.001	11.00	-3.54	p<0.001
KK5	60	8.00	-4.05	p<0.001	8.00	-4.79	p<0.001
KW5	61	7.00	-4.41	p<0.001	13.00	-2.70	p<0.01
LS5	62	5.00	-5.14	p<0.001	12.00	-3.12	p<0.01
OB5	63	11.00	-2.96	p<0.01	13.00	-2.70	p<0.01
OP5	64	5.00	-5.14	p<0.001	11.00	-3.54	p<0.001
PBS5	65	20.00	0.32	ns	20.00	0.23	ns
RB5	66	15.00	-1.50	ns	19.00	0.19	ns
RH5	67	1.00	-6.59	p<0.001	13.00	-2.70	p<0.01
RW5	68	20.00	0.32	ns	20.00	0.23	ns
SH5	69	22.00	1.04	ns	22.00	1.06	ns
TN5	70	12.00	-2.59	p<0.01	12.00	-3.12	p<0.01
AG6	71	7.00	-4.41	p<0.001	12.00	-3.12	p<0.01
CC6	72	13.00	-2.23	p<0.05	14.00	-2.28	p<0.05
EC6	73	6.00	-4.77	p<0.001	7.00	-5.21	p<0.001
HL6	74	5.00	-5.14	p<0.001	12.00	-3.12	p<0.01
HM6	75	18.00	-0.41	ns	18.00	- 0.61	ns
KH6	76	22.00	1.04	ns	22.00	1.06	ns
TC6	77	13.00	-2.23	p<0.05	18.00	- 0.61	ns
TM6	78	10.00	-3.32	p<0.001	17.00	-1.03	ns
JC7	79	23.00	1.41	ns	23.00	1.48	ns
SC7	80	16.00	-1.14	ns	17.00	-1.03	ns

Appendix 7.2: Clinical children (n=40): DDK Accuracy total score (binary /24) and DDK mean rate scores (secs/syll), compared to the typical group mean scores.

Key: A=Accuracy; R=Rate; ns =not significant; sig.=significant; not sig; =not significant; z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level. *=EW4 did not complete all subtests.

Child's ID	Child's No.	Accuracy Total /24	Z score	Sig./not sig.	Mean rate per syllable	Z score	Sig./not sig.
AJ4	41	11.00	-2.96	p<0.01	.32	2.25	p<0.05
DC4	42	3.00	-5.87	p<0.001	.28	1.25	ns
EW4	43	*			*		
JJ4	44	6.00	-4.77	p<0.001	.35	3.00	p<0.01
LR4	45	10.00	-3.32	p<0.001	.29	1.50	ns
MP4	46	13.00	-2.23	p<0.05	.36	3.25	p<0.01
PG4	47	3.00	-5.87	p<0.001	.26	0.75	ns
SB4	48	3.00	-5.87	p<0.001	.31	2.00	p<0.05
TB4	49	12.00	-2.59	p<0.01	.29	1.50	ns
TH4	50	3.00	-5.87	p<0.001	.34	2.75	p<0.01
ChS5	51	19.00	-0.05	ns	.24	0.01	ns
CS5	52	2.00	-6.23	p<0.001	.55	8.00	p<0.001
DG5	53	14.00	-1.87	p<0.05	.22	-0.25	ns
EN5	54	13.00	-2.23	p<0.05	.31	2.00	p<0.05
IF5	55	16.00	-1.14	ns	.41	4.50	p<0.001
IT5	56	10.00	-3.32	p<0.001	.39	4.00	p<0.001
JB5	57	9.00	-3.68	p<0.001	.30	1.75	p<0.05
JC5	58	23.00	1.41	ns	.27	1.00	ns
JK5	59	3.00	-5.87	p<0.001	.24	0.01	ns
KK5	60	8.00	-4.05	p<0.001	.26	0.75	ns
KW5	61	7.00	-4.41	p<0.001	.34	2.75	p<0.05
LS5	62	5.00	-5.14	p<0.001	.33	2.50	p<0.01
OB5	63	11.00	-2.96	p<0.01	.32	2.25	p<0.05
OP5	64	5.00	-5.14	p<0.001	.26	0.75	ns
PBS5	65	20.00	0.32	ns	.28	1.25	ns
Child's	Child's	Accuracy	Z score	Sig./not	Mean	Z score	Sig./not

ID	No.	Total /24		sig.	rate per syllable		sig.
RH5	67	1.00	-6.59	p<0.001	.26	0.75	ns
RW5	68	20.00	0.32	ns	.25	0.50	ns
SH5	69	22.00	1.04	ns	.29	1.50	ns
TN5	70	12.00	-2.59	p<0.01	.31	2.00	p<0.05
AG6	71	7.00	-4.41	p<0.001	.24	0.01	ns
CC6	72	13.00	-2.23	p<0.05	.25	0.50	ns
EC6	73	6.00	-4.77	p<0.001	.35	3.00	p<0.01
HL6	74	5.00	-5.14	p<0.001	.25	0.50	ns
HM6	75	18.00	-0.41	ns	.19	-1.00	ns
KH6	76	22.00	1.04	ns	.24	0.01	ns
TC6	77	13.00	-2.23	p<0.05	.43	5.00	p<0.001
TM6	78	10.00	-3.32	p<0.001	.27	1.00	ns
JC7	79	23.00	1.41	ns	.33	2.50	p<0.01
SC7	80	16.00	-1.14	ns	.36	3.25	p<0.01

Appendix 7.3: Clinical children (n=40): DDK accuracy, DDK consistency and DDK rate profiles compared to typical group means.

Key: A=Accuracy; C=Consistency; R=Rate; *=EW4 did not complete all subtests.

However based on what she did produce, her profile is indicated within ( ).

Child's ID.	Child's No.	A & C	A & R	A, C, R Profile
AJ4	41	A C	A R	ACR
DC4	42	A	A	A
EW4	43	(AC)	(AR)	(ACR)
JJ4	44	A C	A R	ACR
LR4	45	A C	A	AC
MP4	46	A	A R	AR
PG4	47	A	A	A
SB4	48	A C	A R	ACR
TB4	49	A C	A	AC
TH4	50	A	A R	AR
ChS5	51	ns	ns	ns
CS5	52	A C	A R	ACR
DG5	53	A	A	A
EN5	54	A C	A R	ACR
IF5	55	ns	R	R
IT5	56	A	A R	AR
JB5	57	A C	A R	ACR
JC5	58	ns	ns	ns
JK5	59	A C	A	AC
KK5	60	A C	A	AC
KW5	61	A C	A R	ACR
LS5	62	A C	A R	ACR
OB5	63	A C	A R	ACR
OP5	64	A C	A	AC
PBS5	65	ns	ns	ns
RB5	66	ns	R	R
RH5	67	A C	A	AC
RW5	68	ns	ns	ns
SH5	69	ns	ns	ns
TN5	70	A C	A R	ACR
AG6	71	A C	A	AC
CC6	72	A C	A	AC
EC6	73	A C	A R	ACR
HL6	74	A C	A	AC
HM6	75	ns	ns	ns
KH6	76	ns	ns	ns
TC6	77	A	A R	AR
TM6	78	A	A	A
JC7	79	ns	R	R
SC7	80	ns	R	R

Appendix 8.1: Clinical and typical children (n=40): Mispronunciation detection task: raw scores and percentage scores.

Key: Child's No. =Child's number; Child's ID. =Child's identification; *= child did not complete all blocks.

Child's No.	Child's ID. Clinical	Score /60	% score	Child's No.	Child's ID Typical	Score /60	% score
41	AJ4	54.00	90.00	1	AL4	56.00	93.00
42	DC4	*	80.00	2	An4	52.00	87.00
43	EW4	*	93.00	3	Ann4	53.00	88.00
44	JJ4	56.00	93.00	4	Bel4	30.00	50.00
45	LR4	46.00	77.00	5	BN4	57.00	95.00
46	MP4	53.00	88.00	6	Is4	60.00	100.00
47	PG4	42.00	70.00	7	Ja4	49.00	82.00
48	SB4	51.00	85.00	8	Jo4	56.00	93.00
49	TB4	52.00	87.00	9	Ma4	60.00	100.00
50	TH4	57.00	95.00	10	Ni4	52.00	87.00
51	ChS5	59.00	98.00	11	Re4	59.00	98.00
52	CS5	43.00	72.00	12	AB5	60.00	100.00
53	DG5	36.00	60.00	13	AL5	51.00	85.00
54	EN5	56.00	93.00	14	Anl5	60.00	100.00
55	IF5	59.00	98.00	15	Ao5	54.00	90.00
56	IT5	55.00	92.00	16	CE5	59.00	98.00
57	JB5	53.00	88.00	17	Da5	56.00	93.00
58	JC5	60.00	100.00	18	EL5	57.00	95.00
59	JK5	53.00	88.00	19	Ha5	56.00	93.00
60	KK5	54.00	90.00	20	Is5	59.00	98.00
61	KW5	57.00	95.00	21	Lo5	59.00	98.00
62	LS5	57.00	95.00	22	Ra5	57.00	95.00
63	OB5	51.00	85.00	23	Rh5	58.00	97.00
64	OP5	57.00	95.00	24	Ro5	57.00	87.00
65	PBS5	60.00	100.00	25	SO5	59.00	98.00
66	RB5	56.00	93.00	26	Ta5	60.00	100.00
67	RH5	47.00	78.00	27	Xa5	53.00	88.00
68	RW5	57.00	95.00	28	Za5	55.00	92.00
69	SH5	58.00	97.00	29	CM16	60.00	100.00
70	TN5	59.00	98.00	30	CM26	57.00	95.00
71	AG6	55.00	92.00	31	DK6	60.00	100.00
72	CC6	58.00	97.00	32	HM6	57.00	95.00
73	EC6	57.00	95.00	33	JM6	60.00	100.00
74	HL6	57.00	95.00	34	KB6	58.00	97.00
75	HM6	57.00	95.00	35	NB6	58.00	97.00
76	KH6	59.00	98.00	36	RS6	57.00	95.00
77	TC6	55.00	92.00	37	SB6	55.00	92.00
78	TM6	57.00	95.00	38	DQ7	59.00	98.00
79	JC7	58.00	97.00	39	DR7	60.00	100.00
80	SC7	53.00	88.00	40	EO7	59.00	98.00

Appendix 8.2. Individual clinical children (n=40): Mispronunciation detection scores compared to typical group's mean scores.

Key: Child's No. =Child's number; Child's ID. =Child's identification; *= child did not complete all blocks; sig.=significant; not sig.=not significant.z= +/- 1.65 is significant at p<0.05 level; z=+/-2.33 is significant at p<0.01 level; z=+/-3.29 is significant at p<0.001 level.

Child No.	Child's ID	Score /60	% score	z score	Sig./not sig.
41	AJ4	54.00	90.00	-0.43	ns
42	DC4	*	80.00	-1.59	ns
43	EW4	*	93.00	-0.08	ns
44	JJ4	56.00	93.00	-0.08	ns
45	LR4	46.00	77.00	-1.94	p<0.05
46	MP4	53.00	88.00	-0.66	ns
47	PG4	42.00	70.00	-2.76	p<0.01
48	SB4	51.00	85.00	-1.01	ns
49	TB4	52.00	87.00	-0.78	ns
50	TH4	57.00	95.00	0.15	ns
51	ChS5	59.00	98.00	0.50	ns
52	CS5	43.00	72.00	-2.53	p<0.01
53	DG5	36.00	60.00	-3.93	p<0.001
54	EN5	56.00	93.00	-0.08	ns
55	IF5	59.00	98.00	0.50	ns
56	IT5	55.00	92.00	0.50	ns
57	JB5	53.00	88.00	-0.66	ns
58	JC5	60.00	100.00	0.74	ns
59	JK5	53.00	88.00	-0.66	ns
60	KK5	54.00	90.00	-0.43	ns
61	KW5	57.00	95.00	0.15	ns
62	LS5	57.00	95.00	0.15	ns
63	OB5	51.00	85.00	-1.01	ns
64	OP5	57.00	95.00	0.15	ns
65	PBS5	60.00	100.00	0.74	ns
66	RB5	56.00	93.00	-0.08	ns
67	RH5	47.00	78.00	-1.83	p<0.05
68	RW5	57.00	95.00	0.15	ns
69	SH5	58.00	97.00	0.39	ns
70	TN5	59.00	98.00	0.50	ns
71	AG6	55.00	92.00	-0.20	ns
72	CC6	58.00	97.00	0.39	ns
73	EC6	57.00	95.00	0.15	ns
74	HL6	57.00	95.00	0.15	ns
75	HM6	57.00	95.00	0.15	ns
76	KH6	59.00	98.00	0.50	ns
77	TC6	55.00	92.00	-0.20	ns
78	TM6	57.00	95.00	0.15	ns
79	JC7	58.00	97.00	0.39	ns
80	SC7	53.00	88.00	-0.66	ns

Appendix 8.3: Clinical children (n=40) DEAP Oro-motor subtests: raw scores, standard scores and percentiles.

Key: Child's No. =Child's number; Child's ID. =Child's identification; IM =Isolated movements; SM =Sequenced movements; St. Score=Standard score; *=Outside the age range of the DEAP; **= child did not complete tasks

Child's No.	Child's ID.	IM Raw Score	IM St. Score	P/centile	SM Raw score	SM St. score	P/ centile
41	AJ4	9.00	8.00	25.00	12.00	8.00	25.00
42	DC4	10.00	10.00	50.00	14.00	10.00	50.00
43	EW4	10.00	10.00	50.00	16.00	12.00	75.00
44	JJ4	10.00	9.00	37.00	15.00	11.00	63.00
45	LR4	10.00	10.00	50.00	16.00	12.00	75.00
46	MP4	10.00	9.00	37.00	16.00	12.00	75.00
47	PG4	11.00	10.00	50.00	18.00	13.00	84.00
48	SB4	10.00	9.00	37.00	16.00	12.00	75.00
49	TB4	12.00	11.00	50.00	18.00	13.00	84.00
50	TH4	12.00	10.00	50.00	18.00	13.00	84.00
51	ChS5	9.00	5.00	5.00	14.00	8.00	25.00
52	CS5	7.00	3.00	1.00	11.00	5.00	5.00
53	DG5	12.00	10.00	50.00	18.00	12.00	75.00
54	EN5	12.00	10.00	50.00	18.00	12.00	75.00
55	IF5	12.00	10.00	50.00	15.00	9.00	37.00
56	IT5	10.00	7.00	16.00	14.00	9.00	37.00
57	JB5	10.00	7.00	16.00	16.00	10.00	50.00
58	JC5	12.00	10.00	50.00	18.00	11.00	63.00
59	JK5	10.00	7.00	16.00	16.00	10.00	50.00
60	KK5	10.00	7.00	16.00	18.00	11.00	63.00
61	KW5	10.00	7.00	16.00	15.00	9.00	37.00
62	LS5	9.00	5.00	5.00	15.00	9.00	50.00
63	OB5	10.00	7.00	16.00	16.00	10.00	50.00
64	OP5	10.00	7.00	16.00	18.00	12.00	75.00
65	PBS5	9.00	5.00	5.00	15.00	9.00	37.00
66	RB5	10.00	7.00	16.00	18.00	11.00	63.00
67	RH5	10.00	7.00	16.00	16.00	10.00	50.00
68	RW5	12.00	10.00	50.00	18.00	12.00	75.00
69	SH5	12.00	10.00	50.00	15.00	9.00	37.00
70	TN5	9.00	5.00	5.00	15.00	9.00	37.00
71	AG6	9.00	3.00	1.00	15.00	7.00	16.00
72	CC6	8.00	3.00	1.00	14.00	7.00	16.00
73	EC6	**			**		
74	HL6	10.00	6.00	9.00	15.00	7.00	16.00
75	HM6	7.00	3.00	1.00	13.00	6.00	9.00
76	KH6	10.00	3.00	1.00	18.00	10.00	50.00
77	TC6	8.00	3.00	1.00	12.00	3.00	1.00
78	TM6	10.00	6.00	9.00	18.00	10.00	50.00
79	JC7	8.00	* (3.00)	*(1.00)	15.00	*(7.00)	*(16.00)
80	SC7	11.00	* (6.00)	* (9.00)	16.00	*(8.00)	* (25.00)

Appendix 8.4: Clinical children (n=40): Percentage single consonant sounds correct with reference to age norms (Dodd et al., 2002) and consonants not produced correctly but expected for age.

Key: Child's No. =Child's number; Child's ID. =Child's identification

Child's No.	Child's ID.	% accurate	Consonants not produced correctly
41	AJ4	95.00	ŋ
42	DC4	69.00	g j l tʃ dʒ
43	EW4	94.00	z ʒ dʒ
44	JJ4	100.00	
45	LR4	78.00	ŋ v z tʃ dʒ ʒ
46	MP4	95.00	ŋ
47	PG4	67.00	k g l ŋ z tʃ dʒ ʒ
48	SB4	75.00	ŋ z tʃ dʒ ʒ
49	TB4	75.00	ŋ v tʃ dʒ ʒ
50	TH4	80.00	s z dʒ ʒ
51	ChS5	81.00	ʃ ŋ z tʃ
52	CS5	71.00	ʃ ŋ dʒ ʒ
53	DG5	100.00	
54	EN5	100.00	
55	IF5	95.00	z
56	IT5	57.00	b d g s ʃ z tʃ dʒ ʒ
57	JB5	95.00	l
58	JC5	76.00	s z ʃ tʃ dʒ
59	JK5	81.00	ŋ tʃ dʒ ʒ
60	KK5	81.00	l tʃ dʒ ʒ
61	KW5	75.00	s ʃ z tʃ dʒ ʒ
62	LS5	90.00	ʒ dʒ
63	OB5	81.00	ʃ tʃ dʒ ʒ
64	OP5	76.00	ʃ z tʃ dʒ ʒ
65	PBS5	100.00	
66	RB5	90.00	tʃ dʒ
67	RH5	90.00	ʒ d
68	RW5	81.00	ʃ tʃ dʒ ʒ
69	SH5	76.00	ʃ ŋ tʃ dʒ ʒ
70	TN5	100.00	
71	AG6	64.00	s ŋ v z tʃ dʒ r ʒ
72	CC6	91.00	r ʒ
73	EC6	91.00	r dʒ
74	HL6	91.00	g ŋ
75	HM6	95.00	ʃ
76	KH6	86.00	s ʃ z
77	TC6	77.00	ʃ ŋ tʃ dʒ ʒ
78	TM6	77.00	ʃ tʃ dʒ r ʒ
79	JC7	100.00	
80	SC7	96.00	ŋ

Appendix 8.5: Individual clinical children (n=40): DEAP Phonology PCC raw scores, standard scores, percentiles and number and type of age appropriate, delayed and unusual phonological error patterns[l] ([l]according to criteria of Dodd et al.,2002).

Key: Child's No. =Child's number; Child's ID. =Child's identification; st. score =standard score; EP=Error patterns; age app. =age appropriate; Gl=gliding; CR=Cluster reduction; FCD=Final consonant deletion; MCD=Medial consonant deletion; ICD=Initial consonant deletion; St.=Stopping; Fr=Fronting; Bk=Backing; pref.=preference; Glot.=Glottalisation; V=Voicing; Vow=Vowel error; WSD=Weak syllable deletion; Aff=Affrication; Non EC=Non English consonants.

Child's ID.	PCC score	St. score	Centile	Age App. EP	Delayed EP	Unusual EP
AJ4	81.00	5.00	5.00	1 Gl	0	0
DC4	25.00	3.00	1.00	2 Gl CR	3 Fr St FCD	1 /h/ pref
EW4	30.00	3.00	1.00	1 CR	3 Fr St FCD	1 MCD
JJ4	86.00	7.00	16.00	0	0	0
LR4	67.00	3.00	1.00	2 Gl CR	2 St FCD	1 MCD
MP4	74.00	4.00	2.00	0	1 Fr	0
PG4	34.00	3.00	1.00	2 Gl CR	2 Fr FCD	2MCD Glot
SB4	44.00	3.00	1.00	2 Gl CR	3 Fr St FCD	1 /h/ pref
TB4	68.00	3.00	1.00	2 Gl CR	0	0
TH4	61.00	3.00	1.00	1 CR	1 V	1 Bk
ChS5	81.00	3.00	1.00	1 Gl	0	0
CS5	34.00	3.00	1.00	0	4 Fr CR FCD WSD	2 MCD Vow
DG5	72.00	3.00	1.00	1 Gl	0	0
EN5	69.00	3.00	1.00	1 Gl	0	0
IF5	82.00	3.00	1.00	0	1 CR	1 /h/ pref
IT5	42.00	3.00	1.00	1 Gl	2 CR FCD	3 ICD MCD Glot.
JB5	67.00	3.00	1.00	1 Gl	1 CR	1 /j/ pref
JC5	67.00	3.00	1.00	1 Gl	0	0
JK5	56.00	3.00	1.00	1 Gl	3 Fr V CR	0
KK5	38.00	3.00	1.00	0	3 CR St FCD	1 Vow
KW5	64.00	3.00	1.00	1 Gl	0	1 Bk
LS5	51.00	3.00	1.00	1 Gl	3 V St CR	0
OB5	66.00	3.00	1.00	1 Gl	1 Fr	0
OP5	37.00	3.00	1.00	1 Gl	3 Fr St CR	1 Non-E C
PBS5	87.00	5.00	5.00	1 Gl	0	1 Vow
RB5	71.00	3.00	1.00	1 Gl	2 Fr CR	0
RH5	53.00	3.00	1.00	1 Gl	1 CR	2 Bk /f/ pref
RW5	79.00	3.00	1.00	1 Gl	0	0
SH5	68.00	3.00	1.00	1 Gl	1 CR	0
TN5	91.00	6.00	9.00	1 Gl	0	0
AG6	44.00	3.00	1.00	0	3 Fr St CR	1 Aff.
CC6	65.00	3.00	1.00	0	2 Gl CR	0
Child's ID.	PCC score	St. score	Centile	Age App. EP	Delayed EP	Unusual EP
HL6	77.00	3.00	1.00	0	2 Fr Gl	0
HM6	94.00	7.00	16.00	0	0	0
Child's	PCC	St. score	Centile	Age App.	Delayed	Unusual

ID.	score			EP	EP	EP
TC6	51.00	3.00	1.00	0	3 Fr CR FCD	1 /h/ pref
TM6	52.00	3.00	1.00	0	3 Fr Gl CR	1 /f/ pref in clusters
JC7	86.00	*(3.00)	*(1.00)	0	1 Gl	1 Vow
SC7	75.00	*(3.00)	*(1.00)	0	2 Gl CR	0
				25/40	27/40	19/40

NB JC7 and SC7 were above the age range of the DEAP Phonology Assessment. Standard scores and percentiles (marked with *) were produced compared to the top age range 6;06 -6;11 years.

Appendix 8.6 Individual clinical children (n=40): Phonological error patterns on DEAP Phonology Assessment, which could affect one or more of the consonants included in DDK targets.

Key: Child's No. =Child's number; Child's ID. =Child's identification; * =partially accounted for by articulatory error pattern; ** fully accounted for by articulatory error pattern; EPs=Error patterns

Child's ID.	Fronting	Gliding affecting /l/	Backing	Stopping affecting /f/	Voicing	No. of EPs
AJ4	No	Yes	No	No	No	1
DC4	Yes*	Yes **	No	Yes	No	3 (1* & 1**)
EW4	Yes	No	No	Yes	No	2
JJ4	No	No	No	No	No	0
LR4	No	No	No	No	No	0
MP4	Yes	No	No	No	No	1
PG4	Yes **	Yes **	No	No	No	2 (both**)
SB4	Yes	No	No	No	No	1
TB4	No	No	No	No	No	0
TH4	No	No	Yes	No	Yes	2
ChS5	No	No	No	No	No	0
CS5	Yes	Yes	No	No	No	2
DG5	No	No	No	No	No	0
EN5	No	No	No	No	No	0
IF5	No	No	No	No	No	0
IT5	No	No	No	No	No	0
JB5	No	Yes **	No	No	No	1 (**)
JC5	No	No	No	No	No	0
JK5	Yes	No	No	No	Yes	2
KK5	No	No	No	No	No	0
KW5	No	No	Yes	No	No	1
LS5	No	No	No	No	Yes	1
OB5	No	Yes	No	No	No	1
OP5	Yes	Yes	No	Yes	No	3
PBS5	No	No	No	No	No	0
RB5	Yes	Yes	No	No	No	2
RH5	No	Yes	Yes*	No	No	2
RW5	No	No	No	No	No	0
SH5	No	No	No	No	No	0
TN5	No	Yes	No	No	No	1
AG6	Yes	No	No	No	No	1
CC6	No	Yes	No	No	No	1
EC6	No	No	No	No	Yes	1
HL6	Yes*	No	No	No	No	1 (*)
HM6	No	No	No	No	No	0
KH6	No	No	No	No	No	0
TC6	Yes	No	No	No	No	1
TM6	Yes	Yes	No	No	No	2
JC7	No	No	No	No	No	0
SC7	No	No	No	No	No	0

Appendix 8.7 Clinical children (n=16): DEAP Inconsistency Assessment percentage scores and DDK Consistency scores (binary).

Key: Child's No. =Child's number; Child's ID. =Child's identification;

Child's No.	Child's ID	Percentage inconsistency score	Inconsistency score over 40%	Consistency /24
41	AJ4			12.00
42	DC4			18.00
43	EW4			
44	JJ4			9.00
45	LR4			10.00
46	MP4			17.00
47	PG4	20.00	No	18.00
48	SB4			13.00
49	TB4			14.00
50	TH4			16.00
51	ChS5			19.00
52	CS5	72.00	Yes	2.00
53	DG5			17.00
54	EN5			13.00
55	IF5			17.00
56	IT5	21.00	No	17.00
57	JB5			14.00
58	JC5			23.00
59	JK5			11.00
60	KK5	52.00	Yes	8.00
61	KW5	24.00	No	13.00
62	LS5	21.00	No	12.00
63	OB5	32.00	No	13.00
64	OP5	20.00	No	11.00
65	PBS5			20.00
66	RB5			19.00
67	RH5			13.00
68	RW5	8.00	No	20.00
69	SH5	8.00	No	22.00
70	TN5			12.00
71	AG6	24.00	No	12.00
72	CC6	24.00	No	14.00
73	EC6	26.00	No	7.00
74	HL6			12.00
75	HM6			18.00
76	KH6			22.00
77	TC6	16.00	No	18.00
78	TM6			17.00
79	JC7	20.00	No	23.00
80	SC7	28.00	No	17.00

Appendix 8.8 Clinical children (n=40): Connected speech rate in seconds per syllable.

Key: Child's No. =Child's number; Child's ID. =Child's identification; Mean = .39, s.d. 0.8.

Child's ID	Child's No	Connected speech rate	s.d.
AJ4	41	.26	+ 1.0 -1.5 s.d.
DC4	42	.31	within +/- 1 s.d.
EW4	43	.37	within +/- 1 s.d.
JJ4	44	.39	within +/- 1 s.d.
LR4	45	.22	+ 2.0 s.d.
MP4	46	.42	within +/- 1 s.d.
PG4	47	.35	within +/- 1 s.d.
SB4	48	.40	within +/- 1 s.d.
TB4	49	.51	-1.5 s.d.
TH4	50	.46	within +/- 1 s.d.
ChS5	51	.31	within +/- 1 s.d.
CS5	52	.57	-2.0 -2.5 s.d.
DG5	53	.37	within +/- 1 s.d.
EN5	54	.34	within +/- 1 s.d.
IF5	55	.41	within +/- 1 s.d.
IT5	56	.38	within +/- 1 s.d.
JB5	57	.35	within +/- 1 s.d.
JC5	58	.37	within +/- 1 s.d.
JK5	59	.40	within +/- 1 s.d.
KK5	60	.46	within +/- 1 s.d.
KW5	61	.39	within +/- 1 s.d.
LS5	62	.30	+ 1.0 -1.5 s.d.
OB5	63	.36	within +/- 1 s.d.
OP5	64	.39	within +/- 1 s.d.
PBS5	65	.44	within +/- 1 s.d.
RB5	66	.49	- 1.0 -1.5 s.d.
RH5	67	.31	within +/- 1 s.d.
RW5	68	.37	within +/- 1 s.d.
SH5	69	.46	within +/- 1 s.d.
TN5	70	.27	+1.5 s.d
AG6	71	.41	within +/- 1 s.d.
CC6	72	.44	within +/- 1 s.d.
EC6	73	.41	within +/- 1 s.d.
HL6	74	.51	-1.5 s.d
HM6	75	.32	within +/- 1 s.d.
KH6	76	.30	+ 1.0 -1.5 s.d.
TC6	77	.42	within +/- 1 s.d.
TM6	78	.33	within +/- 1 s.d.
JC7	79	.53	-1.5-2.0 s.d.
SC7	80	.45	within +/- 1 s.d.

Appendix 8.9: Clinical children's scores on DEAP subtests (Dodd et al., 2002)

Key: Child's ID=Child's identification; Oro-M=oro-motor; IM=isolated movements; SM=sequenced movements; std.=standard score; PCC=percentage consonants correct; a/app.=age appropriate; Incon. Asess=Inconsistency Assessment; Gl=gliding; CR=cluster reduction; Fr=fronting; St=stopping; FCD=final consonant deletion; ICD=initial consonant deletion; MCD=medial consonant deletion; V=voicing; pref.=preference; back=backing; WSD=weak syllable deletion.

Child's ID	Age	Articulation Vowels %	Articulation Consonants %	Articulation Errors	Oro-M IM std.	Oro-M SM std.	Oro-M DDK std.	Phonology PCC raw score	Phonology PCC std. score	Errors A/app.	Errors Delayed	Errors Unusual	Incon. Assess %
AJ4	4;09	100.00	95.00	ŋ	8.00	8.00	8.00	81.00	5.00	Gl			
DC4	4;04	100.00	69.00	g j l tʃ dʒ	10.00	10.00	10.00	25.00	3.00	Gl, CR	Fr St FCD	/h/ pref	
EW4	4;01	100.00	94.00	z ʒ dʒ	10.00	12.00	10.00	30.00	3.00	CR	Fr St FCD	MCD	
JJ4	4;08	100.00	100.00		9.00	11.00	8.00	86.00	7.00				
LR4	4;04	100.00	78.00	ŋ v z tʃ dʒ ʒ	10.00	12.00	10.00	67.00	3.00	Gl CR	St FCD	MCD	
MP4	4;08	100.00	95.00	ŋ	9.00	12.00	8.00	74.00	4.00		Fr		
PG4	4;04	83.00	67.00	k g l ŋ z tʃ dʒ ʒ	10.00	13.00	10.00	34.00	3.00	GL, CR	Fr FCD	MCD [ʔ] pref	20.00
SB4	4;09	100.00	75.00	ŋ z tʃ dʒ ʒ	9.00	12.00	8.00	44.00	3.00	GL, CR	Fr St FCD	/h/ pref	
TB4	4;11	100.00	75.00	ŋ v tʃ dʒ ʒ	11.00	13.00	8.00	68.00	3.00	GL, CR			
TH4	4;08	100.00	80.00	s z dʒ ʒ	10.00	13.00	8.00	61.00	3.00	CR	V	Back	
ChS5	5;06	100.00	81.00	ʃ ŋ z tʃ	5.00	8.00	11.00	81.00	3.00	Gl			
CS5	5;09	89.00	71.00	ʃ ŋ dʒ ʒ	3.00	5.00	9.00	34.00	3.00		Fr CR FCD WSD	MCD Vowel E	72.00
DG5	5;02	100.00	100.00		10.00	12.00		72.00	3.00	Gl			
EN5	5;00	100.00	100.00		10.00	12.00	7.00	69.00	3.00	Gl			
IF5	5;00	100.00	95.00	z	10.00	9.00		82.00	3.00		CR	/h/ pref	
IT5	5;01	100.00	57.00	b d g s ʃ z tʃ dʒ ʒ	7.00	9.00		42.00	3.00	Gl	CR FCD	ICD MCD [ʔ] pref	21.00
JB5	5;02	94.00	95.00	l	7.00	10.00	11.00	67.00	3.00	Gl	CR	/j/ pref	

Child's ID	Age	Articulation Vowels %	Articulation Consonants %	Articulation Errors	Oro-M IM std.	Oro-M SM std.	Oro-M DDK std.	Phonology PCC raw score	Phonology PCC std. score	Errors A/app.	Errors Delayed	Errors Unusual	Incon. Assess %
JC5	5;10	100.00	76.00	s z ʃ tʃ dʒ	10.00	11.00	11.00	67.00	3.00	Gl			
JK5	5;11	100.00	81.00	ŋ tʃ dʒ ʒ	7.00	10.00	8.00	56.00	3.00	Gl	Fr V CR		
KK5	5;10	88.00	81.00	l tʃ dʒ ʒ	7.00	11.00		38.00	3.00		CR St FCD		52.00
KW5	5;05	100.00	75.00	s ʃ z tʃ dʒ ʒ	7.00	9.00		64.00	3.00	Gl		Back	24.00
LS5	5;11	100.00	90.00	ʒ dʒ	5.00	9.00		51.00	3.00	Gl	V St CR		21.00
OB5	5;07	100.00	81.00	ʃ tʃ dʒ ʒ	7.00	10.00		66.00	3.00	Gl	Fr		32.00
OP5	5;02	94.00	76.00	ʃ z tʃ dʒ ʒ	7.00	12.00		37.00	3.00	Gl	Fr St CR	Non-E C	20.00
PBS5	5;07	83.00	100.00	(Vowel errors only)	5.00	9.00	8.00	87.00	5.00	Gl		Vowel E	
RB5	5;09	100.00	90.00	tʃ dʒ	7.00	11.00	11.00	71.00	3.00	Gl	Fr CR		
RH5	5;11	100.00	90.00	ʒ d	7.00	10.00	8.00	53.00	3.00	Gl	CR	Back /f/ pref	
RW5	5;01	100.00	81.00	ʃ tʃ dʒ ʒ	10.00	12.00		79.00	3.00	Gl			8.00
SH5	5;03	100.00	76.00	ʃ ŋ tʃ dʒ ʒ	10.00	9.00	11.00	68.00	3.00	Gl	CR		8.00
TN5	5;06	100.00	100.00		5.00	9.00	9.00	91.00	6.00	Gl			
AG6	6;00	100.00	64.00	s ŋ v z tʃ dʒ r ʒ	3.00	7.00	8.00	44.00	3.00		Fr St CR	Affric	24.00
CC6	6;03	94.00	91.00	r ʒ	3.00	7.00		65.00	3.00		Gl CR		24.00
EC6	6;04	94.00	91.00	rdʒ				52.00	3.00		V CR FCD		26.00
HL6	6;02	100.00	91.00	g ŋ	6.00	7.00	8.00	77.00	3.00		Fr Gl		
HM6	6;03	100.00	95.00	ʃ	3.00	6.00		94.00	7.00				
KH6	6;09	94.00	86.00	s ʃ z	3.00	10.00		81.00	3.00				
TC6	6;04	94.00	77.00	ʃ ŋ tʃ dʒ ʒ	3.00	3.00		51.00	3.00		Fr CR FCD	/h/pref	16.00
TM6	6;04	100.00	77.00	ʃ tʃ dʒ r ʒ	6.00	10.00		52.00	3.00		Fr Gl CR	/f/ pref	
JC7	7;08	94.00	100.00	Vowel errors	3.00*	7.00*		86.00	3.00*		Gl	Vowel E	20.00
SC7	7;09	89.00	96.00	ŋ	6.00*	8.00*		75.00	3.00*		Gl CR		28.00

Appendix 8.10: Linguistic Profiles of Individual Children (N=16) On Dodd's Linguistic Classification

Key: X=difficulty noted; Oro-M=Oro-motor assessment; PCC=Percentage consonants correct; Inconsis.=Inconsistency Assessment.

Child's ID	Age	Oro-M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsis.	Subgroup
AJ4	4;09		X	X				
DC4	4;04		X	X	X	X		
EW4	4;01		X	X	X	X		
JJ4	4;08							
LR4	4;04		X	X	X	X		
MP4	4;08		X	X	X			
PG4	4;04		X	X	X	X		Consistent phonological disorder + articulation difficulties.
SB4	4;09		X	X	X	X		
TB4	4;11		X	X				
TH4	4;08		X	X	X	X		
ChS5	5;06	X	X	X				
CS5	5;09	X	X	X	X	X	X	Developmental verbal dyspraxia
DG5	5;02			X				
EN5	5;00			X				
IF5	5;00		X	X	X	X		
IT5	5;01		X	X	X	X		Consistent phonological disorder + articulation difficulties
JB5	5;02		X	X	X	X		
JC5	5;10		X	X				
JK5	5;11		X	X	X			
KK5	5;10		X	X	X		X	Inconsistent phonological disorder + articulation difficulties
KW5	5;05		X	X		X		Consistent phonological disorder + articulation difficulties
LS5	5;11	X	X	X	X			Phonological delay + articulation difficulties.
OB5	5;07		X	X	X			Phonological delay + articulation difficulties.
OP5	5;02		X	X	X	X		Consistent phonological disorder + articulation difficulties.

Child's ID	Age	Oro-M	Articulation	Phonology PCC	Errors Delayed	Errors Unusual	Inconsis.	Subgroup
PBS5	5;07	X	X (V)	X				
RB5	5;09		X	X	X			
RH5	5;11		X	X	X	X		
RW5	5;01		X	X				Articulation difficulties.
SH5	5;03		X	X	X			Phonological delay + articulation difficulties.
TN5	5;06	X		X				
AG6	6;00	X	X	X	X	X		Consistent phonological disorder +articulation difficulties
CC6	6;03		X	X	X			Phonological delay + articulation difficulties.
EC6	6;04		X	X	X			Phonological delay + articulation difficulties.
HL6	6;02	X	X	X	X			
HM6	6;03	X	X					
KH6	6;09	X	X	X				
TC6	6;04	X	X	X	X	X		Consistent phonological disorder +articulation difficulties
TM6	6;04	X	X	X	X			
JC7	7;08	X	X (vowels)	X	X	X		Consistent phonological disorder + articulation difficulties
SC7	7;09	X	X	X	X			Phonological delay + articulation difficulties

NB JC7 and SC7 were out of the age range of the DEAP Test. Difficulties noted were recorded in comparison to the top age range 6;06-6;11 years.

Appendix 8.11: Psycholinguistic Profiles of individual clinical children (Stackhouse and Wells, 1997)

Key: X=difficulty shown; reps=representations: RW=real word; NW=non-word; SS=syllable sequences; Oro-M=oro-motor; sg.=single; rep.=repetition

Child's ID.	Age	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro-M/sg. Sounds/ SS rep x 1
AJ4	4;09		X	X	X	X XX	XX
DC4	4;04		X	X	X	XXX	XX
EW4	4;01		X	X	X	XX	X
JJ4	4;08				X	XXX	X
LR4	4;04	X	X	X	X	XX	X
MP4	4;08		X	X	X	XX	XX
PG4	4;04	X	X	X	X	XXX	XX
SB4	4;09		X	X	X	XXX	XX
TB4	4;11		X			XX	XX
TH4	4;08		X	X	X	XXX	XX
ChS5	5;06		X				XX
CS5	5;09	X	X	X	X	XXX	XXX
DG5	5;02	X	X			X	
EN5	5;00		X			X	
IF5	5;00		X			X	XX
IT5	5;01		X	X	X	XXX	XX
JB5	5;02		X	X	X	XXX	X
JC5	5;10		X				X
JK5	5;11		X	X	X	XXX	XX
KK5	5;10		X	X	X	XXX	XX
KW5	5;05		X	X	X	XXX	XX
LS5	5;11		X	X	X	XXX	XXX
OB5	5;07		X	X		XX	XX
OP5	5;02		X	X	X	XXX	XX

Child's ID.	Age	Reps. Input	Motor Program Naming	Motor Program RW rep x 1	Motor Programming NW rep x 1	Motor Planning RW NW SS x5	Motor execution Oro/s/sounds/SS rep x 1
PBS5	5;07		X				XX
RB5	5;09		X		X	XX	XX
RH5	5;11	X	X	X	X	XXX	XX
RW5	5;01		X				X
SH5	5;03		X				X
TN5	5;06		X				XX
AG6	6;00		X	X	X	XXX	XXX
CC6	6;03		X		X	XX	XX
EC6	6;04		X	X	X	XXX	XX
HL6	6;02		X	X	X	XXX	XXX
HM6	6;03						XX
KH6	6;09		X				XX
TC6	6;04		X	X		XX	XXX
TM6	6;04		X	X	X	XXX	XXX
JC7	7;08		X				XX
SC7	7;09		X			XX	XX

Appendix 8.12: Individual clinical children’s case details using WHO ICF-CY

Child’s ID.	Body Structures	Body functions	Activity & Participation	Personal & environmental factors
		Difficulties with:		
AJ4		Articulation; DDK (ACR)		Bilingual home; history of more severe speech difficulties
DC4		Articulation; DDK (A)	Awareness & distress	Started SLT intervention recently.
EW4		Articulation; DDK (ACR)	Awareness & distress	
JJ4		Articulation; DDK (ACR)		History of more severe speech difficulties
LR4		Articulation; DDK (AC); Speech discrimination		Family history of speech difficulties
MP4		Articulation; DDK (AR)		History of more severe speech difficulties
PG4		Articulation; DDK (A); Speech discrimination; rhythm	Awareness	Family history of speech difficulties
SB4		Articulation; DDK (ACR); fluency	Awareness	Family history of speech difficulties
TB4		Articulation; DDK (AC); hoarse voice		History of language delay & more severe speech difficulties
TH4		Articulation; DDK (AR)		History of language delays; social issues
ChS5		Articulation; oro-motor		History more severe speech difficulties
CS5	Microcephaly	Articulation; oro-motor; DDK (ACR); auditory discrimination; loud voice; rhythm; slow rate	Persisting expressive language delay; Motor co-ordination difficulties.	Attends Speech and Language Resource Base within a mainstream primary school.
DG5		Articulation; DDK (A); Speech discrimination;		Bilingual home; History more severe speech difficulties; History of glue ear/conductive hearing loss (grommets fitted at 4;06 years)
EN5		Articulation; DDK (ACR)		History more severe speech difficulties
IF5		Articulation; DDK (R)		History more severe speech difficulties; parental anxiety high.

Child's ID.	Body Structures	Body functions	Activity & Participation	Personal & environmental factors
		Difficulties with:		
JB5		Articulation; DDK (ACR); loud voice		History more severe speech difficulties
JC5		Articulation		History of expressive language delay; Twin also has speech difficulties (less severe)
JK5		Articulation; DDK (AC)	Recall difficulties	Family history of literacy difficulties
KK5		Articulation; DDK (AC)		Bilingual home; history of expressive language delay
KW5	Cleft palate (repaired); Pierre Robin Sequence; Fistula	Articulation; DDK (ACR)		Parental anxiety
LS5		Articulation; oro-motor; DDK (ACR)	Awareness	
OB5		Articulation; DDK (ACR)		History more severe speech difficulties
OP5		Articulation; DDK (AC); hypo-nasal resonance; soft voice		History of glue ear & conductive hearing loss
PBS5		Articulation; oro-motor; breath support;	Awareness; anxiety	History more severe speech difficulties
RB5		Articulation ; DDK (R)	Poor attention & listening	History of language delays & more severe speech difficulties
RH5		Articulation; DDK (AC); speech discrimination	Poor attention & listening	
RW5		Articulation; creaky voice		Family history of speech & language difficulties; History of language delay & more severe speech difficulties
SH5		Articulation		
TN5		Articulation; oro-motor; DDK (ACR); loud voice	Motor co-ordination difficulties	History of language delay & more severe speech difficulties
AG6		Articulation; oro-motor; DDK (AC)	Awareness	
CC6	Class III malocclusion	Articulation; oro-motor; DDK (AC)		History of more severe speech difficulties; Tonsil & Adenoidectomy at 2;06 years
EC6		Articulation; DDK (ACR) NB not compliant for oro-motor tasks)	Aware; challenging behaviour	Family history of severe speech difficulties (older sibling)

Child's ID.	**Body Structures**	**Body functions**	**Activity & Participation**	**Personal & environmental factors**
		Difficulties with:		
HL6		Articulation; oro-motor; DDK (AC); hyponasal resonance	Awareness & distress	Bilingual home; history of expressive language delay; History of glue ear/conductive hearing loss (grommets fitted at 3;03 years
HM6	Tongue tie	Articulation; oro-motor ; rapid speech rate		
KH6	Top incisors missing	Articulation; oro-motor		Sucked thumb in past
TC6		Articulation; oro-motor; DDK (AR); monotonous voice; slow rate	Awareness & distress; expressive language delay; motor co-ordination difficulties; literacy difficulties	Family history of speech, language & literacy difficulties
TM6		Articulation; oro-motor; DDK (A)	Awareness	Family history of speech difficulties
JC7	Tongue tie (released)	Articulation; oro-motor; DDK (R); slow speech rate	Motor co-ordination difficulties	History of expressive language delay & more severe speech difficulties
SC7	Bifid uvula; vocal nodules	Articulation; DDK (R); very hoarse voice; slow speech rate	Severe persisting language disorder; literacy difficulties	Trilingual environment (English shared language of parents); attends a speech and language resourced school.